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CONTENTS.

	PAGE.
Sugar-Cane Commodities	261
Recent Work on Sugar Cane Soils....	263
Moth-Borer Damage in relation to Sugar-Cane Varieties in British Guiana	264
Books Presented	271
World Sisal Production	271
Studies in Tropical Land Tenure (2)	272
Uniformity Trials on Cacao	277
The Fruitfulness of Cacao	288
A Variety Test on Sugar-Cane	290
Reviews	293
Sugar Notes	294
Chemical Notes	295
Trend of the Markets	296

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SUGAR-CANE COMMODITIES.

THE sugar-cane provides an excellent and instructive example of a natural cheap material whose commercial value may ultimately depend on the diversity and cost of manufacture of the component products that can be isolated from it. In these respects, it resembles many other natural materials, both mineral, animal and vegetable, as, for instance, coal, common salt, and lime-stone; domestic animals and fish; oil palms and cereal plants. The history of the technical exploitation by man of these, and many other similar materials, indicates that, in almost every case, primary utilisation has depended on the easy extraction of a single valuable component. Thus, coal was first utilised for the manufacture of crude illuminating gas (apart, of course, for its direct employment as a source of heat energy), salt for soda, limestone for mortar, animals for fat, leather and fibre, fish for oil, palms for useful fats, and cereals for starch. Subsequently, increasing chemical and technical knowledge of the composition and properties of the natural materials, coupled with man's increasing need for diverse and new chemical substances have led to the manufacture of numerous by-products, and have induced the development of off-shoots from the main industries. One has but to recall the profound modifications and elaborations that have occurred within the past fifty years in the utilisation of coal and of sulphuric acid derived from natural sulphur compounds, to appreciate the magnitude and importance of these developments. Coal now furnishes (in addition to coal-gas and various forms of solid fuel), by-product ammonia, synthetic nitrogen compounds, and nitrogenous manures, hydrocarbon oils for internal combustion engines, and even edible fats. Sulphuric acid now forms the key-stone of a great number of important ancillary industries that have been built round the sulphuric acid plant.

The general principles involved, and the great significance of chemical and technological research implied in the onward march of progress are especially well illustrated in the cane-sugar industry. It is within the recollection of living man that the only product of importance derived from sugar-cane was muscovado sugar. The process of manufacture was simple but crude, and the by-products were limited to molasses and rum. Until recent times further development was restricted mainly to the production of a purer product, a refinement largely due to the consumers' fastidiousness. Nevertheless, severe competition also led to greatly improved methods

of cane-sugar extraction, to centralisation of factories, and lastly, to increased sugar production in the field through the creation of new varieties of plant, and better management of soil and crop. Indeed, developments along these lines had become so intensified that it almost appeared that further progress would be unattainable.

In recent years, however, an entirely new outlook in the cane-sugar industry has arisen through increasing attention paid to by-products. The first object of intensive study was alcohol derived from molasses by fermentation. The industrial alcohol problem in itself has furnished incentive for much research, both technical and economic. Whilst the problem is not yet acute nor important enough to warrant universal attention, nevertheless it has received serious consideration in those countries where mineral oils are scarce, and where costs of fuel transport decide local prices. Thus, in Queensland and in the West Indies, industrial alcohol derived from molasses is not at present a profitable commodity, but in South Africa considerable developments have followed on the successful adaptation of natalite spirit in internal combustion engines.

Apart from alcohol, many other by-products of molasses have recently been investigated, and their commercial utilisation examined in relation to their possible competition with like substances derived from other sources; for example, glycerine, furfural, acetone, yeast, carbonic oxide gas (used in aerated drinks), solid carbonic oxide (used as "dry ice" in refrigeration) and, more recently still, oxalic acid and citric acid. Of these, glycerine and citric acid have already affected the markets originally controlled by the soap industry and by the citrus products industry respectively.

More striking still have been the recent rapid developments in the manufacture of commodities from waste sugar-cane fibre (bagasse). Celotex board first came into prominence but ten years ago, when its manufacture was proved to be commercially profitable in Louisiana. Here coal is sufficiently cheap partly to replace bagasse as fuel in the sugar factories. Furthermore, the employment of cane varieties having a relatively high content of fibre has increased the available sources of bagasse, so that, in some Louisiana factories, cane-sugar has almost been relegated to the position of a secondary product. Another cane-fibre commodity, namely, vazcane board (invented by E. A. Vasquez in Cuba five years ago), offers considerable commercial promise, and still other fibre products, such as coarse wrapping or soil "mulching" paper and artificial silk, are receiving increasing consideration. Quite recently it has been suggested that moulded articles may be cheaply made from bagasse suitably treated with caustic soda, steam, sulphuric acid and lime, so as to render it plastic and capable of setting under pressure into hard durable objects, such as boards and blocks for buildings.

Besides these direct derivatives, bagasse contains cane-wax of use in the preparation of boot polishes, and provides a source of wood sugar (xylose), acetic and lactic acids, carbon-dioxide gas, charcoal briquettes, an absorbent medium for nitroglycerine explosive, and for molasses used as feeding stuff.

The extended utilisation of bagasse for these various purposes in any particular country or locality will naturally depend on the relative value of cane-fibre as fuel. Thus, in Queensland, coal costs nearly four times the value of wet bagasse, so that here it would obviously be unprofitable to sacrifice the residual fuel value of sugar-cane for the purpose of manufacturing fibre products, unless their realised selling price becomes adequately high. Furthermore, wood paper pulp at present prices costs less in Sydney than paper pulp manufactured from bagasse.

There are still other by-products of the modern cane-sugar factory that deserve greater attention than they so far have received. These include furnace-ash and flue-dust, which contain most of the mineral nutrient elements of the cane plant, notably potash. The ground clinker provides a good basis for brick-making. At least these materials should be spread on the land, or used for composting into organic manures, along with cane-trash, surplus bagasse, and nitrogenous waste from the rum distillery.

Finally, attention is being centred on possible further uses of cane-sugar itself, quite apart from its direct employment as food, or as a medium for preserving canned fruits. As long ago as 1906, a syndicate of French sugar refiners offered a prize of one hundred thousand francs to anyone who could demonstrate new uses for sugar that might involve the utilisation of quantities of the order of one hundred thousand tons. So far the prize has not been claimed, although many uses of sugar have been suggested at various times. Among these are its employment in the manufacture or processing of tanning materials, leather, dyestuffs, transparent soaps, explosives, and pharmaceutical preparations such as antiseptic dressings for the treatment of wounds. Sugar has also been used for removing lime from treated hides, and from certain mineral mixtures; for impregnating wood in order to lessen shrinkage and to repel termites; for preparing calcium sucrate, employed in the preparation of ice cream, and copper sucrate used as insecticide.

Recent research at the Mellon Institute in Pittsburgh, described at the meeting of the American Chemical Society at New Orleans in March this year, indicates that cane-sugar may be successfully used for the preparation of numerous other derivatives such as sucrose acetate and sucrose benzoate, that may find employment as adhesives and lacquers, and in the fabrication of paper. By treating sugar with acids at high temperatures, a product called levulinic acid (acetyl propionic acid) is produced; this may be caused to combine with simple alcohols to yield esters that have valuable solvent properties

for organic substances such as nitroglycerine. The effect of adding sugar to mixtures of lime and sand in the making of mortar was also described. Thus the addition of six per cent. of sugar to the lime used in making mortar was found to increase its strength by some sixty per cent. At the present low price of sugar, it is urged that sugar should become a regular component of mortar mixtures. The practice of incorporating sugar into mortar mixtures has long been known in sugar-producing countries. Thus, low-grade molasses has been regularly used by masons in Barbados where mortar and cement made by its inclusion are much preferred to products devoid of sugar. Whilst white plaster requires white sugar in its composition, fire-brick furnace linings can be more firmly fixed by molasses-sugar plaster than by fire clay.

The future status of the cane-sugar factory may perhaps be likened to that at present obtaining in certain branches of the heavy-chemical industry, where the sulphuric acid plant forms a central unit, around which other process plants, depending on the application of sulphuric acid, are conveniently arranged. It is not necessarily a Utopian dream to visualise the central cane-sugar factory as a nucleus of future tropical chemical works where many of the products and by-products above indicated may be manufactured on a large scale, and where certain dependent industries, such as fruit canning and preserving, and commercial alcohol distilling, are operated in close conjunction.

RECENT WORK ON SUGAR-CANE SOILS.

[*Note.—The following abstract, taken from the "International Sugar Journal" for May, 1932, summarises a paper presented by Professor F. Hardy, at the International Sugar Conference, held at Puerto Rico in March, 1932. An abstract of another paper by the same author was presented in the July issue.*—EDITOR.]

Some Aspects of Cane Soil Surveying.

(*Bull.* 63.)

THE soil survey which is of direct use to the planter growing crops on land which has long been under cultivation, is that which is termed the "physiological-ecological" survey. It attempts periodically to measure and to plot on maps as many of the fluctuating factors controlling crop growth as can reasonably be investigated in field and laboratory. The success of the survey is dependent upon an accumulation of detailed knowledge and experience of the yielding capacity and productivity of the land.

The main growth factors are: (1) water supply, (2) nutrient supply, (3) oxygen supply, (4) temperature, (5) root room, and (6) absence of harmful agencies, and the author proceeds to describe a simple technique for measuring the more important of these, namely, water supply, nutrient supply and acidity or alkalinity. In these there occurs a fluctuation throughout the growing season and from season to season, and hence measurements must be taken at frequent intervals; a cinematograph picture, rather than a snap-shot, is aimed at.

Water Supply.

"Available" water is measured by the wilting coefficient (W), *i.e.*, the weight percentage of water present at the wilting point. The wilting coefficient bears a definite relation to the hygroscopic coefficient (H), such that $W=1.47H$. Further, the hygroscopic coefficient bears a simple relation to the moisture content at point of stickiness (P), such that, for alumino-siliceous soils, $P=4.2H$. Hence $W=0.4P$. For sandy soils, an approximate correction requires to be made such that $W=0.4\ (P-S/5)$, where S is the weight percentage of the coarse-and-fine sand. P-S/5 is known as the "Index of Soil Texture". Determinations are readily made of the index of texture, and can be used for the construction of wilt maps. From determinations of "gross soil moisture content", the amount of available water is readily determined.

Nutrient Supply.

Since "available" plant nutrients are believed to occur mainly as equilibrated ions partly dissolved in the soil solution and partly absorbed at the particle surfaces, methods of estimating total nutrient supply should involve at least the soil solution and the exchangeable ionic layer, if not also the more highly dispersed soil colloid matter. Since, further, a soil sample from land supporting a crop represents only residues, attempts to measure the concentration of free ions have little value, and what is required is a determination of "nutrient supplying ability". Simple methods of measuring this depend on the comparison of fresh samples and others kept in contact with water. Atkin's electrical conductivity method fails to differentiate between the ions, and the phenol disulphonic acid method may be used for determining "nitrifying power", and the ceruleomolybdate test for phosphate supplying ability. All three are suitable for ecological survey work, and preferable to the older citric-soluble technique.

Excessive Acidity and Alkalinity.

Since soil reaction is a static rather than a dynamic factor, pH maps possess permanent value. Lime requirement is important, but depends on soil texture as well as on reaction and can be determined by a simple electrometric method devised by the author. If soil samples are grouped into textural types on a basis of "index of texture", and these groups sub-divided according to intensity of the "exchange reaction", only a few measurements need be made of lime-deficiency.

MOTH-BORER DAMAGE IN RELATION TO SUGAR-CANE VARIETIES IN BRITISH GUIANA.

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That certain varieties of sugar-cane are more resistant than others to attack by sugar-cane moth-borers, *Diatraea* spp., is recognised both by entomologist and sugar-planter, and in some countries where the subject has received attention, certain varieties of sugar-cane have been pronounced as being more resistant than others to the attacks of these insects. On the whole, however, little attention has been given to this aspect of the moth-borer problem, probably not as much as it deserves. In British Guiana, although this character of resistence of certain canes has been recognised to some extent in a general way, no investigation on the subject has been undertaken prior to those reported here.

Wolcott (7) has given the average infestation (stalk) of several varieties of cane in Puerto Rico and states, "Whatever may be the cause of the difference in infestation of the varieties, its practical importance to the cane-grower is that when it is practicable to grow Yellow Caledonia and Cavengirie, and possibly B. 3412, borer infestation is automatically reduced".

Rosenfeld and Barber (4), as quoted by Box (1), state, as the result of field observations in Argentina, "We would recommend the planting, as far as possible, of the thinner, harder types of canes, which do not suffer from the attacks of sugar-cane borers to nearly the same extent that the larger and softer types of canes do". Rosenfeld (5) attributes the difference in borer infestation between the POJ and native canes to the increased fibre content of the former, and states "The increased fibre content of these canes, which is particularly manifested in additional hardness of the rind and internodes, makes penetration into the inner tissues of the cane by the moth-borer a very much more difficult matter than in such canes as *Rayada, Cristalina* or *Santa Cruz* 12 (4), and, probably more important yet in its effect on the composition of the juice and in the reduction in extraction which follows heavy borer attack . . . "

In support of this, the following table of fibre content as determined at the Tucuman Sugar Experiment Station, is given :—

Variety.	*Per cent. fibre in canes.*
POJ 36	12.80
do. 105	13.27
do. 213	13.00
do. 234	12.20
Rayada	10.60
Average POJ	12.82

Following on this work, Holloway and Haley (3) investigated the extent of damage by moth-borer to the Java seedlings in Louisiana, comparing the borer infestation of these with the old established varieties in that country, D74 and *Louisiana Purple.* As the result of their work, these authors came to the conclusion that "It appears from these results that the new varieties are not borer resistant by any means, but that POJ 213, on the other hand, is rather attractive to borer". In explanation of the difference in the results obtained in Louisiana with the reports of borer resistance in Argentina, they add "The new varieties have given a number of 'stubble' crops in Argentina as against one or two stubble crops of the old varieties. This means that less and less cane is planted and more and more springs up year after year from the stubble. Now it has been found that a dangerous source of borer infestation is in the planted stalks, the borer larvae developing in the stalks and the issuing adults making their way through the slight covering of soil ready to oviposit on plants of the grass family. Thus, the less cane there was planted, the fewer borers were planted in the stalks, and as more and more of the long-stubbling Java varieties were planted the number of hibernating larvae were progressively reduced". Nevertheless, from the figures published it would appear that certain of the varieties are less attacked than others.

Box (1) further investigated this question of resistance to moth-borer attack of POJ canes in Argentina. After reviewing the available evidence, this writer considered that, in the light of recent investigations, the theory more likely to be correct in accounting for the noticeable decrease in *Diatraea* infestation in Argentina during the period following the introduction of the Java seedlings, was a succession of severe winters.

Another point brought out by this writer is that different POJ canes may belong to different categories so far as borer attack is concerned, and in this connection he states "The experience of the present writer based upon a number of careful counts of infested POJ 36 and 213 growing under identical conditions as regards soil, age, position, &c. (generally the samples examined were from alternating rows of the two varieties in the same plot), in the grounds of this Experiment Station, supplemented by similar counts made in cane fields in different parts of the province, is that the POJ 213 is invariably considerably more attacked by *Diatraea* than the POJ 36, the intensity of the attack of the former cane seeming

to approximate more to that of the large, soft type of cane exemplified by the *Criolla* canes, in spite of the relative hardness due to increased fibre content as compared with those varieties, and in spite of the relative similarity between its fibre content with that of the POJ 36".

Tables are then given showing the infestations of these canes in Argentina and in Louisiana, representing, in the former, data obtained by himself, and, in the latter instance, by Holloway and Haley, and from these the following has been abstracted :—

Variety.	Louisiana.		Argentina.	
	Per cent. Stalks bored.	Intensity Index.	Per cent. Joints infested.	Intensity Index.
POJ 36	37	1.6	23.4	4.6
POJ 234	59	2.3	....	....
POJ 213	89	3.7	36.1	6.0
Louisiana Purple (=Morada)	89	2.0		

It is stated also "that the POJ 2725 can be grouped with the 213 and the *Kassoer* cane with POJ 36, as regards borer infestation", and further "the degree of infestation of POJ 213 and POJ 2725 (joint infestation being used as a basis for comparison) approaches more to that of the 'native' type of cane than to the POJ 36, which would appear to possess a decided resistance to *Diatraea*, showing that one cannot compare POJ canes as a class with those exemplified by the Cheribon type as another class, in this respect".

That the question of the resistance to moth-borer attack of different varieties of sugar-cane has not received more attention is probably due to the difficulty of carrying out well laid-out experiments in which the results obtained can be examined statistically, and the true value of the data secured thus determined. With other factors such as location of fields, soil conditions, &c., each playing its part (if even at present still not understood) on the final results, unless the layout of the experiment is satisfactory from the point of view of modern experimental practice, the data obtained must always be open to criticism, and the value of the information considerably reduced.

A few months ago, an opportunity offered to carry out an examination of certain varieties of sugar-cane in connection with their damage by moth-borers, in which it appeared that the requirements as regards experimental lay-out were fulfilled, and an investigation of this subject was undertaken by the writer. The results obtained in this investigation appear to be sufficiently definite to warrant their publication, and to show the necessity of further investigation of this subject along similar lines. Arrangements are being made, therefore, to carry out further work along these lines during the present year.

The investigation consisted of the examination of two fields of cane, laid down as variety trials at the British Guiana Sugar Experiment Station, one being plant canes (Field E. 13), and the other, 1st ratoons (Field W.13). The fields were

		Similar Varieties not in Experiment.							
5 D 835/18	10 D 689/13	15 POJ 2725	20 D 351/20	25 D 695/13	30 POJ 2727	35 SC 12.4	40 D 557/20	45 D 625	50 POJ 2725
4 D 625	9 D 557/20	14 SC 12.4	19 D 835/18	24 POJ 2725	29 SC 12.4	34 D 351/20	39 D 689/13	44 POJ 2727	49 D 351/20
3 POJ 2725	8 SC 12.4	13 D 689/13	18 D 625	23 D 351/20	28 D 557/20	33 D 625	38 D 835/18	43 D 695/13	48 D 689/13
2 D 695/13	7 POJ 2727	12 BH 10 (12)	17 D 557/20	22 D 689/13	27 BH 10 (12)	32 POJ 2725	37 D 695/13	42 D 557/20	47 BH 10 (12)
1 D 351/20	6 BH 10 (12)	11 POJ 727	16 D 695/13	21 D 625	26 D 835/13	31 BH 10 (12)	36 POJ 2727	41 D 835/18	46 SC 12.4
		Similar Varieties not in Experiment.							

Blocks I II III IV V

Fig. 1.—Plan of Field, Plant Canes (E.13). Showing arrangement of Varieties of Cane in Plots. Acreage of Field, 4 acres 132 roods. Area of 1 plot=0.060 acre.

laid out in randomised plots; in the plant field there being 50 plots (ten varieties in five replicates), and in the ratoon field, one hundred plots (ten varieties in ten replicates). In each field the varieties used were the same, and consisted of BH 10(12), SC 12.4, POJ 2725, POJ 2727, and the following Experiment Station seedlings not yet in cultivation; D689/13, D695/13, D835/18, D351/20 and D557/20, together with D625, the standard cane of the Colony, for comparison. Plans showing the lay-out of these fields, are given in Figs. 1 and 2. As far as general lay-out of the fields is concerned, the requirements appear to be met.

The damage by small moth-borer was estimated as "final infestation" of stalks and joints bored, and was taken by making counts of one hundred stalks of each variety in each field. Thus, in the plant canes, a sample of twenty stalks was examined in each plot, and in the ratoon canes, a sample of ten stalks was examined in each plot. In these samples of canes, which were selected at random, the number of stalks bored by moth-borer was counted, as well as the total number of joints and the number of joints bored by moth-borer, every joint showing a boring, however small, being considered as a bored joint. From the counts, the percentage of stalks and joints bored was estimated.

The infestation by *Diatraea*, both of stalks and joints for the different varieties in the experiments, of plant canes and 1st ratoons, as obtained in these examinations, are given in Table I.

				Three	Rows	not in	Experiment.					
Dam Bed. Not in Experiment.	Bed not in Experiment.	10 D 835/18	20 POJ 2725	30 D 695/13	40 SC 12.4	50 D 625	60 D 695/13	70 D 835/18	80 D 689/13	90 D 695/13	100 D 689/13	Bed not in Experiment. Dam Bed. Not in Experiment.
		9 D 557/20	19 SC 12.4	29 POJ 2725	39 D 351/20	49 POJ 2727	59 D 625	69 BH 10 (12)	79 D 557/20	89 D 625	99 POJ 2727	
		8 POJ 2725	18 D 689/13	28 D 351/20	38 D 625	48 D 695/13	58 POJ 2725	68 D 689/13	78 D 695/13	88 BH 10 (12)	98 D 695/13	
		7 D 695/13	17 BH 10 (12)	27 D 689/13	37 POJ 2725	47 D 557/20	57 SC 12.4	67 D 695/13	77 D 625	87 POJ 2727	97 D 835/18	
		6 D 351/20	16 POJ 2727	26 D 625	36 BH 10 (12)	46 D 835/18	56 POJ 2727	66 POJ 2725	76 POJ 2725	86 POJ 2725	96 POJ 2725	
		5 D 625	15 D 351/20	25 POJ 2727	35 D 557/20	45 SC 12.4	55 D 557/20	65 POJ 2727	75 D 351/20	85 D 689/13	95 SC 12.4	
		4 SC 12.4	14 D 835/18	24 SC 12.4	34 D 835/18	44 BH 10 (12)	54 BH 10 (12)	64 D 557/20	74 POJ 2727	84 D 557/20	94 D 351/20	
		3 D 689/13	13 D 625	23 BH 10 (12)	33 D 689/13	43 D 689/13	53 D 689/13	63 D 625	73 BH 10 (12)	83 D 351/20	93 D 557/20	
		2 POJ 2727	12 D 557/20	22 D 557/20	32 D 695/13	42 D 351/20	52 D 835/18	62 D 351/20	72 SC 12.4	82 SC 12.4	92 D 625	
		1 BH 10 (12)	11 D 695/13	21 D 835/18	31 POJ 2727	41 POJ 2725	51 D 351/20	61 SC 12.4	71 D 835/18	81 D 835/18	91 BH 10 (12)	
					Three	Rows	not in	Experiment.				
Blocks		I	II	III	IV	V	VI	VII	VIII	IX	X	

FIG. 2.—Plan of Field 1st Ratoons (W.13). Showing arrangement of Varieties of Cane in Plots. Acreage of Field, 3 acres 145 roods. Area of 1 plot=0.92 acre.

Table I.

Diatraea Infestation of Sugar-Cane Varieties.

Variety of Cane.	Plant Canes.		1st Ratoons.	
	Stalks.	Joints.	Stalks.	Joints.
D 625	95.0	25.89	92.0	24.69
BH 10(12)	84.0	16.06	91.0	18.16
SC 12.4	87.0	16.71	91.0	12.83
POJ 2727	82.0	17.28	90.0	15.40
POJ 2725	93.0	23.52	95.0	17.39
D 689/13	99.0	25.78	98.0	24.22
D 695/13	94.0	27.33	97.0	24.72
D 835/18	98.0	29.67	100.0	23.79
D 351/20	94.0	20.58	86.0	18.36
D 557/20	97.0	25.25	96.0	21.50
Mean	92.30	22.80	93.60	20.10

It will be seen that the stalk infestation averages 92.95 per cent. for all varieties in the two experiments (92.30 per cent. in plant canes, and 93.95 per cent. in 1st ratoons), with a minimum of 82 per cent. (POJ 2727, plant canes), and a maximum of 100 per cent. (D835/18, 1st ratoons). The joint infestation, which is the more indicative figure, is 21.45 per cent. for all varieties in the two experiments (22.80 per cent. in plant canes; and 20.10 per cent. in 1st ratoons) with a minimum of 12.83 per cent. (SC 12.4 1st ratoons) and a maximum of 29.67 per cent. (D835/18, plant canes). D625, the standard cane of the Colony, showed an average infestation of 93.5 per cent. stalks and 25.58 per cent. joints, which figures are in close agreement with the general infestation in other parts of the Colony.

The figures of infestation obtained for the different varieties have been examined statistically, and are given below.

Plant Canes.—Table II gives the infestation of varieties by Block, together with the total and mean for each variety.

Table II.

Plant Canes—*Diatraea* Infestation of Plots.

	D625	BH 10(12)	SC 12.4	POJ 2727	POJ 2725	D 689/13	D 695/13	D 835/18	D 351/20	D 557/20	Total.	Mean.
Block I	34.76	17.61	18.95	17.32	29.80	24.39	32.18	31.88	25.61	20.79	253.29	
Block II	26.46	12.32	14.90	14.71	28.17	27.44	17.05	23.78	20.39	32.00	217.22	
Block III	22.70	19.30	28.51	15.12	16.00	22.34	25.88	29.92	13.96	27.00	220.73	
Block IV	23.91	18.96	8.93	19.82	26.57	26.71	36.71	32.70	18.76	26.68	239.75	
Block V	21.62	12.15	12.30	19.44	17.07	28.05	24.85	30.10	24.22	19.81	209.61	
Total	129.45	80.34	83.59	86.41	117.61	128.93	136.67	148.38	102.94	126.28	1140.60	114.06
Mean	25.89	16.06	16.71	17.28	23.52	25.78	27.33	29.67	20.58	25.25	228.12	22.81

Table III.

Analysis of Variance.

Variance due to	Degrees Freedom.	Sum of Squares of Deviations.	Variance σ^2	$\frac{1}{2}\log_e \sigma^2$
Blocks	4	128.48	32.12	1.7245
Varieties	9	1052.51	116.94	2.3792
Error	36	958.10	26.61	1.6406
Total	49	2139.09	43.65	

	$\frac{1}{2}\log_e \sigma^2$		$\frac{1}{2}\log_e \sigma^2$
Blocks	1.7245	Varieties	2.3792
Error	1.6406	Error	1.6406
Difference "z"	0.0839	Difference "z"	0.7386
for P=.05, z=0.4947 approx.		for P=.05, z=0.4090 approx.	

Standard Deviation $(\sigma) = \sqrt{26.61} = 5.158$

Standard Error of the Mean of 5 plots $= \sqrt{\frac{\sigma^2}{5}} = 2.317$

Standard Error of the Difference between two Means $= \sqrt{\frac{2\sigma^2}{5}} = 3.261$

For P=.05, and n=8, t=2.306 (Fisher (2) Table IV).

Significant Difference $= 3.261 \times 2.306$
$= 7.519$

If the mean infestations of the different varieties in the experiment are now tabulated, and, at the same time each variety infestation is given as percentage of the general mean, it will be easier to make comparisons and to see which differences are significant. This is done in Table IV.

Table IV.

	BH 10 (12)	SC 12.4	POJ 2727	D 351/20	POJ 2725	D 557/20	D 689/13	D 625	D 695/13	D 835/18	General Mean.	Standard Error.	Significant Difference.
Joint Infestation Per cent.	16.06	16.71	17.28	20.58	23.52	25.25	25.78	25.89	27.33	29.67	19.01	2.317	7.51
Per cent. Genl. Mean	85	88	91	108	124	133	135	136	144	156	100	12.18	39.50

The result may be summarized, therefore, by saying that, as regards infestation by small moth-borers as obtained in the experiment in plant canes:

BH 10(12), SC 12.4 and POJ 2727 are significantly less attacked than D557/20 (25.25 per cent. joints bored) and upward.

D 351/20 is significantly less attacked than D 835/18 (29.67 per cent. joints bored) and upward.

and that there is no significant difference in attack between POJ 2725, D 557/20, D 689/13, D 625, D 695/13 and D 835/18.

1st Ratoons.—Figures similar to those given above for plant canes are given below for 1st ratoons in Tables V, VI and VII.

Table V.

1ST RATOONS—*Diatraea* INFESTATION OF PLOTS.

	D 625	BH 10 (12)	SC 12.4	POJ 2727	POJ 2725	D 689/13	D 695/13	D 835/18	D 351/20	D 557/20	Total.	Mean.
Block I	32.40	19.83	16.00	15.26	24.71	22.91	24.51	27.21	14.50	23.14	220.47	
Block II	19.24	13.95	13.98	16.31	12.42	17.86	20.80	27.72	17.28	18.21	177.77	
Block III	24.15	11.80	6.91	14.28	13.04	17.45	19.52	26.21	23.63	10.58	167.57	
Block IV	6.31	8.25	11.32	19.32	10.48	25.04	15.06	21.85	1.11	19.24	137.98	
Block V	18.42	27.68	13.25	14.89	18.58	29.62	33.80	17.41	17.65	18.35	209.65	
Block VI	32.40	16.52	9.83	17.62	21.35	27.30	36.10	26.12	20.07	29.70	237.01	
Block VII	28.81	20.50	14.61	10.92	22.71	27.81	18.85	19.75	25.62	25.62	215.20	
Block VIII	24.66	18.35	14.64	20.35	21.85	31.85	25.21	24.35	23.50	34.48	239.24	
Block IX	33.14	24.12	16.24	11.49	11.69	19.63	24.43	28.62	18.62	17.72	205.70	
Block X	27.43	20.65	11.59	13.58	17.15	22.79	28.98	18.74	21.62	18.00	200.53	
Total	246.96	181.65	128.37	154.02	173.98	242.26	247.26	237.98	183.60	215.04	2011.12	201.11
Mean	24.69	18.16	12.83	15.40	17.39	24.22	24.72	23.79	18.36	21.50	201.11	20.11

Table VI.

ANALYSIS OF VARIANCE.

Variance due to	Degrees of Freedom.	Sum of Squares of Deviations.	Variance σ^2	$\frac{1}{2}\log_e \sigma^2$
Blocks	9	907.43	100.82	2.3065
Varieties	9	1600.87	164.54	2.5515
Error	81	2069.39	25.54	1.6201
Total	99	4577.69	46.23	

Standard Deviation (σ) $= \sqrt{25.54} = 5.053$

Standard Error of the Mean of 10 plots $= \sqrt{\frac{\sigma^2}{10}} = 1.593$

	$\frac{1}{2}\log_e \sigma^2$		$\frac{1}{2}\log_e \sigma^2$
Blocks	2.3065	Varieties	2.5515
Error	1.6201	Error	1.6201
Difference "z"	0.6864	Difference "z"	0.9314
for P=.05, z=0.3702 approx.		for P=.05, z=0.3702 approx.	

Standard Error of the Difference between two Means $= \sqrt{\frac{2\sigma^2}{10}} = 2.258$

For P=.05, and n=18, t=2.101 (Fisher (2) Table IV).

Significant Difference=2.258 × 2.101
=4.744

Table VII.

	SC 12.4	POJ 2727	POJ 2725	BH 10(12)	D 351/20	D 557/20	D 835/18	D 689/13	D 625	D 695/13	General Mean.	Standard Error.	Significant Difference.
Joint Infestation Per cent.	12.83	15.40	17.39	18.16	18.36	21.50	23.79	24.22	24.69	24.72	20.11	1.593	4.74
Per cent. Genl. Mean	64	77	87	91	92	100.1	118	121	122	123	100	7.92	23.57

The results from 1st ratoons may be summarised by saying that, as regards infestation by small moth-borers as obtained in the experiment :

SC 12.4 is significantly less attacked than BH 10 (12) (18.16 per cent. joints bored) and upward.

POJ 2727 is significantly less attacked than D 557/20 (21.50 per cent. joints bored) and upward.

POJ 2725, BH 10 (12) and D 351/20 are significantly less attacked than D835/18 (23.79 per cent. joints bored) and upward,

and that there is no significant difference in attack between D 557/20, D 835/18, D 689/13, D 625 and D 695/13.

That a variety of sugar-cane cannot be selected as a suitable cane to adopt in general cultivation on its resistance to moth-borer attack alone can be readily understood, and resistance to moth-borer damage in a variety is not necessarily an indication of high yield of sugar per acre. Other factors, such as tonnage of cane per acre, percentage of sucrose in juice, vegetative vigour, adaptability to soil and climatic conditions, milling quantities, &c., should all receive consideration, and these, either combined or singly, may out-weigh the single factor of resistance to moth-borer attack.

This point is shown best in the following table (Table VIII), giving the figures of analyses of the canes in these experiments, which has been abstracted from Williams's (6) account of the experiments as variety trials, and to which has been added the joint infestation by moth-borer for each variety.

Table VIII.

PLANTS.						1ST RATOONS.					
Variety.	Cane per acre tons.	Sucrose in cane. %	Glucose ratio.	Sucrose in cane per acre tons.	Borer Infestation joints. %	Variety.	Cane per acre tons.	Sucrose in cane. %	Glucose ratio.	Sucrose in cane per acre tons.	Borer Infestation joints. %
D625	22.52	13.21	6.45	2.99	25.89	D625	21.04	12.99	6.07	2.73	24.69
D835/18	22.79	12.85	5.41	2.93	29.67	D695/13	19.68	13.10	3.66	2.55	24.72
D695/13	22.66	12.69	8.97	2.87	27.33	POJ 2727	20.16	12.00	3.46	2.42	15.40
D351/20	20.57	13.26	4.07	2.71	20.58	POJ 2725	18.24	12.73	3.50	2.34	17.39
POJ 2727	22.78	11.89	5.14	2.71	17.28	D689/13	19.40	11.69	7.07	2.24	24.22
POJ 2725	21.31	12.35	3.66	2.63	23.52	D557/20	17.34	11.80	3.60	2.06	21.50
D557/20	21.66	11.83	4.36	2.56	25.25	D835/18	14.73	12.62	5.69	1.85	23.79
D689/13	21.49	11.74	8.40	2.51	25.78	D351/20	13.60	13.57	4.24	1.84	18.36
BH 10 (12)	17.51	13.16	3.42	2.43	16.06	SC 12.4	14.60	12.29	2.54	1.79	12.83
SC 12.4	19.55	12.17	3.19	2.38	16.71	BH 10 (12)	12.51	13.56	2.86	1.70	18.16

Topsoil.		Subsoil.	Topsoil.		Subsoil.
Acid. Fine Silt.		Neutral. Fine Silt.	Markedly Acid. Heavy Silt.		Acid. Clay.
pH Normal	5.73	6.50	5.17		6.10
Exchange	5.43	6.00	4.67		5.38
Lime Requirement Tons	3.90	1.50	6.10		3.50
Organic Matter Per cent.	1.08	0.48	1.62		0.60
Index of Texture	32	30	43		49

The mention of but a single example will be sufficient to demonstrate this point. In the analyses, the variety D625 heads the tables in yield of sugar per acre, both as plant canes and as ratoons, yet this cane was one of the varieties most heavily attacked by moth-borer in the experiments, but the tonnage of cane produced per acre is high (in the ratoons it is the highest of all the varieties), and there can be little doubt that this has considerably modified the effects of the damage by moth-borer.

The correlation coefficient for percentage of sucrose in cane and percentage of joints bored by *Diatraea* has been worked out for the different varieties of cane in the experiments, both as plants and as ratoons, but in no instance have these figures proved to be significant, although they are highly suggestive. This is not entirely unexpected when it is remembered that the samples on which the estimates of moth-borer damage were made were not the same as those on which the chemical analyses were performed. That there has been exhibited a correlation that is in itself suggestive, is sufficient to justify further investigations in this direction, and arrangements are being made to carry out such work in the near future.

There is, however, yet another factor which must be considered in connection with resistance of varieties of sugar-cane to moth-borer damage and their yield of sugar, and that is, the effect of the same amount of moth-borer damage on different varieties. This has been worked out also, but, in the examples in these experiments, the error has been found to be too large to allow of the figures being considered significant. This again is no doubt due to the difference in the samples, and also probably to the small numbers used. It is hoped also to examine this aspect of the subject on another occasion.

It is noteworthy that the canes BH 10(12) and SC 12.4, which have been shown to be the least attacked by sugar-cane moth-borer, occupy the two lowest places as producers of sugar. In this connection, a fact probably not without its significance, is that both these canes are Barbados seedlings, bred and selected under soil and climatic conditions entirely different from those existing on the heavy and impervious clays of the sugar lands of British Guiana.

In the above paragraphs, it will be observed that the seedling SC 12.4 (Saint Croix or Santa Cruz 12.4) has been considered as a Barbados seedling. It is on record that this seedling was produced in Barbados by Mr. J. R. Bovell, and taken by him to Saint Croix, and, after trial there for several years, was sent out from that Island bearing a Saint Croix number. The parentage of the canes used in the experiment are given below :—

Seedling.	*Parent.*
BH 10 (12) ..	..B. 6835.
SC 12.4 ..	..B. 6835.
POJ 2725 ..	..POJ 2364 x EK 28.
POJ 2727 ..	..POJ 2364 x Batjan.
D625 ..	..Dyer.
D689/13 ..	..D 625.
D695/13 ..	..D 625.
D835/18 ..	..D 625 x D 145.
D351/20 ..	..D 625.
D557/20 ..	..Bourbon.

In reviewing the data obtained the conclusions to be drawn from the two experiments are :—

1. The canes at the British Guiana Sugar Experiment Station are attacked by sugar-cane moth-borers (*Diatraea saccharalis* F. and *Diatraea canella* Hmpsn.) to an extent about equal to that of canes in other parts of the Colony, the cane D625, the standard cane of the Colony, being infested to an extent of 25.29 per cent. of its joints in the two experiments (Plants 25.89 per cent.; 1st ratoons 24.69 per cent.) here reported upon, which figure is in close agreement with the average infestation for this cane in British Guiana. The Experiment Station may be considered therefore as typical of the sugar-growing areas of the Colony as regards moth-borer attack.

2. The canes BH 10(12) and SC 12.4, both Barbados seedlings from the same female parent B.6835, and the Java canes POJ 2725 and POJ 2727, seedlings of the same female parent POJ 2364 with EK 28 and Batjan as male parents respectively, are markedly less attacked than D625 (parent Dyer) and other British Guiana seedlings as represented in the experiments (D689/13, D695/13, D835/18 and D557/20, Experiment Station seedlings still under trial) with the exception of D351/20.

3. The resistance of seedling canes to moth-borer damage would appear to be a character more or less marked in certain varieties, and possibly capable of transmission to the progeny.

4. In view of the marked tendency of the seedling D625 and its progeny as represented in the experiments (with the exception of D351/20), as well as other British Guiana seedlings, to attack by sugar-cane moth-borer (*Diatraea* spp.), and the apparent opposite tendency of seedlings of Barbados as represented by BH 10(12) and SC 12.4, and the Java seedlings as represented by POJ 2725 and POJ 2727, that from the point of view of the control of sugar-cane moth-borers in British Guiana, it would appear to be desirable to introduce these canes and their parents as parents in future work on the production of seedling canes suitable for this Colony.

Summary.

1. Different varieties of sugar-cane have been stated to be more resistant than others to the attacks of sugar-cane moth-borer.

2. Two variety trials, laid out according to modern experimental methods, were examined for moth-borer damage, and the data obtained is given, and a statistical examination made of it.

3. The results obtained show that there is a marked difference as regards resistance to moth-borer damage in different varieties of sugar-cane, and there are indications that such resistance is a character of the variety and possibly capable of transmission.

4. There appears to be a close relationship between the extent of moth-borer damage and the percentage of sucrose in cane, and also that different varieties of sugar-cane are affected to varying degrees by the same amount of moth-borer damage, but the data obtained in the examinations, although very suggestive of these points, does not allow of definite statements.

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BOOKS PRESENTED.

We have to acknowledge with thanks the receipt of the following books which have been presented to the Library :—

AGRICULTURE.

Dawson, E. S.—Farm Management in South Africa. *Central News Agency*, South Africa, 1931. £1 2s. 6d.

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* This paper has not been seen by the writer.

WORLD SISAL PRODUCTION.

THE development of sisal cultivation in British East Africa (Kenya Colony and Tanganyika Territory) and the Netherlands East Indies in recent years has affected the position of Mexico, which for years held the monopoly of world production of this widely used textile. So serious is the position regarded in Mexico that every effort is being made to improve the competitive position of Mexican sisal in the world market.

Up till 1916, Mexican production of sisal comprised nearly 90 per cent. of the world total, but the natural cultivation of other sources of supply was given great stimulus by a series of price increases which began to occur about that time, so that the relative importance of that country's output has since been gradually but inexorably reduced. Last year marked the first time that Mexican sisal production was surpassed by the aggregate of comparative output. In the meantime, the Netherlands East Indies and British East Africa have taken their places as important suppliers of sisal.

Another factor in this transition that increases the difficulty of the Mexican position is that the output of the Netherlands East Indies and British East Africa is true sisal (*Agave sisalana*), while the Mexican product is actually henequen (*Agave fourcroydes*), which is considered by the trade to be slightly inferior in quality. The 1929 world output of sisal or henequen—the two terms being used interchangeably in the trade—has been placed at 229,000 tons, the source being Mexico (101,000 tons), British East Africa (70,000 tons), Netherlands East Indies (52,000 tons), Cuba (3,000 tons), Jamaica and the Bahamas (1,000 tons), and other sources (2,000 tons).

According to a recent issue of *Commerce Reports*, Washington, D.C., an equally important record of changing world sisal supplies is revealed in the import statistics of the United States, which is the world's principal consumer of sisal. As late as 1921, Mexico furnished 90 per cent. of American total requirements of sisal, but, by 1929, the proportion had fallen to 63 per cent., and during the first half of 1930, to 44 per cent. July and August receipts from Mexico showed a further sharp decline to 28 and 39 per cent., respectively, of the total imports. Contrasted with that trend is the growth in United States imports from British East Africa and the Netherlands East Indies, which totalling 34,709 tons last year, represented a gain of no less than 290 per cent. over 1920. The United States total sisal imports from these countries has also increased from 5 per cent. in 1920 to 35 per cent. in 1930.—(*Chamber of Commerce Journal*, Vol. LX, No. 877.)

THE CACAO INDUSTRY OF TRINIDAD.

Section 2 of Part V of Professor Shephard's articles on the Cacao Industry of Trinidad will appear in the October issue of the Journal.

STUDIES IN TROPICAL LAND TENURE.

By H. Martin Leake, sc.d.

(2) The West Indies.

Historical.

Diverse as is the history of the various islands of the British West Indies, they have certain features in common. They were occupied at a time when might was right, and the indigenous population received small shrift at the hands of the conquerors. Throughout, at least in any economic sense, there was a practical elimination of that population. By all the conquering races the land became an object of appropriation, and rights to possession were claimed in accordance with the home custom of the particular conqueror. The fertility of the land well adapted the islands to the raising of tropical produce, tobacco, cacao and, later, sugar, for which there was an assured demand in the temperate countries of the Old World, and estates rapidly multiplied for the production of these. But cultivation, and particularly sugar-cane, required labour and, since the indigenous population failed to adapt itself to the conditions, this population was largely eliminated and other sources drawn on for a labour supply. The slave trade of the West Indies appears to have originated locally based on the indigenous population, for numerous raids between the islands are noted. But it was not an approved trade for, as early as 1687, a Royal Cedula was issued with reference to Trinidad, exempting Indians from taxation for twenty years, and forbidding compulsory service on estates (1). In this matter, Spain appears to have led other nations. Under the pressure of demand, a supply of labour was not to be denied, and it was to Africa that attention was turned. Thus arose, and was established, that approved economic system based on slavery which lasted until the proclamation of emancipation in 1834.

These features are common to all islands though the individual history is, in other respects, very diverse. Though a monopoly in the whole area was originally claimed by Spain, in some islands, as Barbados and Antigua, the only effective occupation has been British. Others, as Jamaica and Trinidad, were wrested from Spain, while yet again others have repeatedly changed hands. The interest of the origins of these settlements is mainly historical, and has but slight bearing on the present discussion. Settlement by plantations is the attraction to colonists, and is the order of the day. It matters little whether these settlements are directly established as the result of Governmental action, or indirectly, as under the patents granted by the Stuart kings to Lord Carlisle and others.

Since the prosperity of the West Indian islands depended upon production, and since, further, they were, in the current view of the time, assets of the home country through the regulation of trade under the Navigation Acts, it is not surprising that the question of increasing their population should be a matter of public concern; and it is not without interest to note the manner in which this increase was sought in those early days. Apart from the deportation of delinquents, which hardly affects the land question, for these were sent to forced labour, definite attempts at settlement in the strict sense of the word, were made. By a Proclamation in 1655 (2) people of the Commonwealth and Dominions were authorized to inhabit and plant in Jamaica under Mr. Noel's patent, and the lands assigned were transferable. In 1661 more specific instructions were given. A Proclamation (13 Chas. II, 1661) granted 30 acres to each person over the age of twelve then resident or taking up residence in the next two years. But the effort at settlement was not limited to the islands under British rule. In Trinidad, then under Spain, a similar effort was made in 1783 when a Cedula was promulgated offering to foreigners, under condition that they were catholics and took the oath of allegiance, to each white person, 32 acres, and 16 acres for each slave. The extent of the grants which at this time appeared attractive, is noteworthy, for they are limited in extent, and hardly conform to the present day acceptation of the term plantation.

The further development of these settlements is confused, mainly owing to the inadequate arrangements for registration or failure to enforce registration. The most advanced system of registration appears to have been developed in the Spanish islands for, in the Cedula of 1783 in relation to Trinidad, specific instructions are laid down for registration and the issue of authenticated copies of the entry to serve as title deeds. But throughout little attention appears to have been given by the land-holders themselves to the securing of such titles. The reason for this is not far to seek; where land is abundant disputes as to title are few, for it is easier to appropriate unclaimed land than to dispute possession. It is only in the smaller islands, where land is restricted, that the need for a title becomes serious. Thus, as early as 1662, the question of titles became the dominating issue for Barbados, and played an important part in the discussions of 1661 onwards as to the relations between the island and the home Government. It is in this connection that Beer (3) writes "The tactical weakness of Barbados in the approaching contest lay in the uncertainty of the land titles of many of the planters. In numerous cases they were defective and of doubtful legality". In Jamaica, too, Long notes in reference to Cromwell's Proclamation, the small attention paid to the usual formalities in conveyancing and transferring landed property while, in Trinidad, Governor Chacon experienced considerable

opposition in the issue of grants under the Cedula of 1783 from colonists who had taken possession and divided among themselves large tracts of the best land of the island, though these had not been surveyed or granted, and were not under cultivation (de Verteuil).

In addition to the small grants which the above extracts indicate to have been sufficient to attract settlers, there were larger properties fully answering to the designation of plantations, and it is noteworthy that there was a gradual absorption of the smaller holdings by the larger throughout. Thus, even at the time Long wrote, he was able to draw attention to the disappearance of small farms. The growth of large estates at this time was dictated partly by climate, partly by the nature of the crop. In Jamaica the former rendered large areas suitable for stock, and hence the development of the ranching, or pen, system for which the island is famous. The cane crop necessitated a stock of cattle and much labour, raising financial considerations which favoured aggregation into large units. The tendency was more marked in the larger islands where, in the absence of any rigid record of rights in land, spheres of influence, subsequently to be developed into definite claims, were more readily established than in the smaller islands where land was strictly limited.

One further point must be briefly mentioned. In the proprietary islands, revenue had to be secured to the proprietors, and this was effected by levies, some two to four per cent., on produce. When the Crown absorbed the proprietary rights, a 4½ per cent. export duty was levied, in return for which titles were confirmed, arrears of proprietary dues voided, and lands granted in free and common socage. In Jamaica, as elsewhere, the question of financing the colony was a serious one, and, in 1661, among other taxes, a quit rent was introduced, a form of tax adopted from Virginia and subsequently introduced elsewhere. Throughout, and to the present day, a quit rent is the only charge on the land as such, and represents the sole interest of the State in the land. There is throughout no partnership between State and Proprietor such as is found in India, though it is noteworthy that an approach to the system was at one time introduced into Trinidad. The Warden's Ordinance of 1849, and, as amended in 1851 and 1852, imposed a tax of £13 per acre for land in canes, £6 10s. for land in other cultivation and 30s. for uncultivated land. In the second Warden's Ordinance of 1852, the rate was simplified to £10 per acre for all cultivated land, and 10s. uncultivated. Further, a triennial assessment was imposed. It is of interest in this connection to note that de Verteuil (4) suggested an assessment on quality of land, a suggestion which, though not carried into effect, conforms even more closely with the Indian system. Instead, in 1879, the assessment, which had in the meantime been altered to 5s. per acre on cultivated land and 3d. on uncultivated, was amended to 1s. per acre on all lands, thus doing away with any question of intermittent assessment.

These conditions of greater or smaller estates, run by slave labour of African origin and frequently with nebulous titles to the land held, characterize the period to the time of emancipation. With the enactment of emancipation and the short period of apprenticeship which followed it, the entire economic system of the islands was uprooted. The first effect of the change was to produce an acute labour shortage; for the emancipated slave, having few wants, turned to all means for securing those wants except that of regular manual labour. The intensity of the shortage varied in different islands. In the larger islands where land was abundant, squatting became prevalent, and raised numerous administrative difficulties. In Jamaica, the difficulties were intensified by attempts to charge rents for the huts and plots on estate lands previously occupied free, action which tended to drive the labour from the estates, led to the establishment of village sites on Crown Lands or abandoned properties, and divorced the labourer from his opening for labour. Thus has arisen that feature, common to so many of the islands, peasant cultivation coterminous with plantations. In Trinidad particularly, a further complication arose from the indenture system, introduced to solve the labour difficulties by the importation of East Indians under contract. Many of these, on completion of their contract, elected to remain in the island, and took up small holdings, frequently aggregated in separate villages, forming communities distinct from the peasantry of African origin.

Perhaps in all this history, the most charateristic feature was the casual regard to the question of title. This appears to have been the case even in the smaller islands, for, in Barbados where, as has been shown, the question of title was prominent as early as 1662, little appears to have been done in the matter, for, in 1745, was passed a Titles Quieting Act (Act 1 of 1745), and, in 1762, it was enacted that sales should be recorded in writing. But it was not till 1891 that a Conveyancing Act (Act 13 of 1891) was passed, enforcing the registration of title deeds. In Trinidad, to take an example of one of the larger islands, attempts had been made by the Spanish Governor to secure registration of titles in the *Libro Becerro* in the course of executing the terms of the Cedula of 1783, but these efforts had been only partially successful. In the period of Sir J. Ralph Woodford (1813-1828), strenuous efforts were made to secure registration, and quit rents were instituted. Later, in 1871, an Ordinance for the declaration of titles to land and for facilitating its transfer was passed; but the machinery laid down was never called into being, and it was not till 1908 that the question of titles was finally settled by the passing of the Real Property Act (Act 49 of 1908). In Jamaica, the abolition of slavery had led to much abandonment of land

which became the object of squatting. Between 1867 and 1887, Government regularized the position by resuming all such abandoned land for which owners with sustainable titles were not forthcoming, and 27,000 acres were resumed.

Crown Lands.

The question of Crown Lands is intimately bound up with the two questions of titles and squatting, and became an important issue only in those islands where culturable land existed in excess. Until the rights in land had been clearly demarcated, a clear policy could not be followed. In Trinidad, Crown Lands were administered under a Court of Intendant, a system taken over from Spanish rule, assisted by a Surveyor-General. In 1845, in the reorganization then effected under which a Survey Department was created under the Public Works Department, an office of Sub-Intendant was established with responsibility for the charge and disposal of Crown Lands. Rules for the alienation of these lands were framed, and these have been modified from time to time. But the alienated lands were invariably allotted in fee simple. Similar rules, differing in minor particulars, are in force in all islands where unclaimed lands occur in sufficient abundance. A certain precision has been given to land alienation in Jamaica by a scheme, initiated in 1897, under which certain areas are demarcated for settlement in small holdings purchasable by direct payment or in instalments, while the East Indian problem has been dealt with on similar lines, ten acres, with one additional acre for each child born in the country, being granted in lieu of a return passage. Government is, further, fostering group settlement of small holders by purchasing and sub-dividing estates which come on to the market.

Plantations.

The evolution of the plantation system has, in large measure, been conditioned by the nature of the preparatory processes of the product. In certain of these, cacao, coconut, cotton, arrowroot and so on, these processes are comparatively simple, and capable of application with a reasonable degree of efficiency on a small scale. In the case of others, notably sugar, this is not so, and these differences are reflected in the evolution of land tenure.

Sugar.—From the earliest times, when muscovado sugar was the standard product, the manufacture from the cane was a relatively complex process; too complex, and requiring too much capital for any but the more wealthy planter working on his own finances. Consequently, in the sugar tracts particularly, occurred that tendency towards absorption of smaller estates which has been already noted. With the arrival of the vacuum pan and other modifications of the process of manufacture, and with the adoption of skilled technical control, the really economic unit became too large even for this method. Under the influence of this development, a threefold evolution arose; the unit remained small, as in Barbados, where a large measure of specialization of product as syrup permitted the retention of the small unit; centralization of the factory processes occurred, the smaller estates, which retained their own identity, supplying canes to the factory, a development, perhaps, characteristic of Jamaica but found elsewhere; aggregation of estates in the hands of large companies with loss of identity of the original units, characteristic, perhaps, of Trinidad, though also found in Jamaica where the number of estates which, at the time the island passed to Britain, was 159, has been reduced to some twelve only. A lead in this process of aggregation was given in 1876 by the formation of the Usine Ste. Madeleine with a factory then capable of producing 5,000 tons sugar and now with an output of over 30,000 tons. As an offshoot of the second of these, may be mentioned a fourth, represented by the Basseterre Factory, opened in St. Kitts in 1912, which is organized on a co-operative basis.

The reflexes which came of this aggregation development, itself the response to economic causes, are of considerable interest, and are best followed in Trinidad. They are a development from the perennial difficulty which arose over labour and the anxiety for an assured supply of cane. In 1882, was introduced by Sir Neville Lubbock a system of cane farming or cultivation by small holders who disposed of their cane to the factories. This system of cane farming, in spite of early set backs, has taken firm root. As the result of the depressions which have subsequently affected the cane industry, the cost of production of cane became one of the major issues for the factories, and, since the price which offered an inducement to the farmer sufficient to produce the cane, proved more economic than production by direct cultivation with paid labour, the development of the system was rapid. By 1900, some 20 per cent. of the canes ground were raised by farmers. The system has had many ups and downs. In 1921 no less than 57 per cent. of the canes ground were farmer produced, while, at the present time, the percentage has fallen to 40. The system has its obvious limits, imposed by the necessity of a supply of canes which can be drawn on at will at the end of the season, or when daily supplies from farmers fall short of factory requirement; for the organization of regular supplies from a host of small and independent units is necessarily difficult.

The causes of these fluctuations offer many points of interest which cannot be discussed in detail here. Essentially it is a question of a balancing of two opposing forces, the desire of the factories for a supply of cane, and the price which will induce the farmer to grow. In periods of boom, such as followed the war, all factories are eager to secure cane to their maximum capacity; advances are eagerly offered against promise of crops. In the absence of mutual

understandings between the factories, a competition between these arose, of which the farmers were not slow to take advantage. The Farmers' Advances Ordinance of 1913 (Ord. 28 of 1913), which made it an offence to deliver canes at the wrong factory, was ineffective to cure the evil, and, in 1922, a Restriction of Area agreement was entered into under which the factories demarcated spheres of influence within which they limited their activities. This agreement, in as far as it created local monopolies, weighted the scales too heavily in favour of the factories, which were only limited by public opinion and by the willingness of the farmers to continue to grow cane, from cutting prices extensively. It was followed, therefore, by a further agreement for uniform rates based on a sliding scale fixed on the F.O.B. price Port-of-Spain, and determined by a Standing Committee appointed by the Governor.

Concurrently with this development of cane farming by independent small holders, a practice arose under which factories leased out small holdings to farming tenants under terms which included the cultivation of a certain portion of the area in cane. The lease sometimes took the form of a legal document, but, more generally, it was unwritten, the advance note being sufficient evidence, and hence determined according to custom. In either case, it is an annual agreement, renewable by consent and terminable at three or six month's notice ending in June. Here again, it is a balancing of two opposing forces. Since the crop is of long growth, with ratoons, some three years on the average, difficulties arose over the question of compensation for growing canes for which compensation on eviction was not originally enforceable. These matters were adjusted by the Agricultural Contracts Ordinance (Ord. 36 of 1925) and the Sugar Cane Small Holdings Ordinance (Ord. 35 of 1928), the latter of which defined a basis for determining compensation to outgoing tenants. These Ordinances are of the nature of tenancy legislation.

Bananas.—Bananas offer an example of economic pressure exerted from another quarter, and the development is characteristic of Jamaica. The product requires no extensive preparatory process, and has merely to be cut at the right degree of ripeness; but, since the market is overseas, and the product is perishable, demanding specific shipping facilities, the unit is a ship-load, and control necessarily rests with the providers of these facilities. Any tendency towards monopoly in this matter could only be met by co-operation among producers. Here, there is no question of land tenure, since supply from any sized unit could be incorporated in a consignment, provided organization regulated supply to the transport facilities. It is in this way, by co-operation, that Jamaica has met the situation. In 1926, the Jamaica Producers' Organization, later the Jamaica Producers' Organizing Association, was formed. Its objects were fostered by Government, legislation being passed to give sanctity to the contracts (Law 5 of 1928), to give a guarantee on debentures (Law 6 of 1928), and to authorize a loan on shipbuilding (Law 25 of 1930). The Association organizes the supplies from growers, ships the fruit in its own bottoms to Europe and England, and arranges the distribution. Payment is made on a truly co-operative basis of an initial payment followed by a further payment calculated on profits.

Cacao.—Trinidad forms the main source of West Indian cacao which shares with sugar the two leading positions among the agricultural products of the island. Though it is the main product of Grenada, the amount produced here is relatively small, while, in Jamaica, it is dominated by sugar and fruits. Owing to the ease with which this product can be prepared for the market, and its relative permanence when so prepared, no pressure is exerted on the industry such as is found in the case of sugar and bananas. The small units can be readily assembled, graded and bulked by the merchants, and there is no urge to aggregation of units, which generally remain small. Pressure arises from another source, the phenomenal growth of the West African production. The West African product is of low grade, and West Indian, to compete, must conform to the higher quality of which it is capable. This, though partly, and to an indeterminate extent, the result of climate and variety, is mainly a question of careful preparation, and efforts have been directed primarily to secure standards of quality which would receive acceptance by the trade, and, secondly, to raise the proportion of high quality produced. A Cacao Planter's Association was first organized in Trinidad in 1905. Its aims are well described by Shephard (5) in the following words, "The main advantage lies in the fact that the Association is able to place on the market a continuous and large supply of good and consistent quality cacao". Owing, however, to the indirect nature of the pressure, the advantages to be derived from co-operation in this endeavour were but slowly appreciated, and progress was equally slow. About 1926, the question of compulsion was mooted, but no action was taken, and, only in 1927, was voluntary grading, undertaken by the Association, introduced. Up to this time any stimulus to produce a high quality product was lacking, for payments were distributed in accordance with quantity irrespective of quality, and it was not till 1931 that the premium on superior grades was passed on to the producers of those grades. The Association has thus taken twenty-six years to establish for itself a position, not only to provide continuous and large supply, but a supply of good and consistent quality product.

Other products.—Neither in the nature of the product nor in the magnitude of production has there lain any stimulus towards aggregation of units, and any movement has been in the direction of co-operation. In 1929, a Citrus Growers' Association and a Pimento Growers' Association were formed in Jamaica, and, in 1930, a Coconut

Producers' Association in the same island. Citrus production on any extended scale is a comparatively recent development; but the market is accustomed to graded fruit of certain standards, and the need for meeting those market requirements, together with the living example of bananas, constitutes the urge. The urge in the last case is somewhat different and of a special nature, the main object being the erection of a factory capable of supplying the local market for edible oil which is now supplied by imports. In St. Vincent, a similar co-operative movement has recently been started in connection with that specialized crop, arrowroot.

Peasantry.

As has been indicated earlier, the origin of an independent peasantry in the larger islands in which land was available for settlement, was the consequence of emancipation. The few wants which slavery had inculcated were readily met from peddling or from the cultivation of a small plot of land. The efflux of emancipated slaves from the estates raised difficult problems in the prevention of squatting, and, even at the present time, when registration is complete, difficulty arises sometimes over the land tax, for a considerable portion of the small holders have a degree of mobility, in part at least due to the demand for labour on the estates, which renders abandoned land common. There is, however, a definite tendency for settlement to take the form of villages, and, in Trinidad with its settled East Indian population, the economic situation reproduces that of a *ryotwari* village, with the difference that it is permanently settled at a low rate represented by the tax or quit rent. The tendency has been fostered by Government as has been sufficiently indicated earlier.

Of tenantry there is little in the sense of a system supporting a landlord on the rents. Tenantry is represented by the cane farming system to which reference has already been made. Here, it is not rent but supplies of cane which form the foundation of the system, and such tenancy legislation as exists refers to the specific case of cane farming. Here and there, efforts have been made to group such tenancies round villages.

In the smaller islands, where suitable land is not available in such abundance, a peasantry has tended to develop in recent years, particularly in Barbados. In the absence of Crown Land, the development which commenced towards the end of last century, and was accelerated during and since the war, took the form of sales of small lots by plantations at high prices on the basis of a small deposit followed by annual instalments, with interest charges, to be completed usually in five years. The reasons for this development are obscure, and almost certainly complex. The underlying cause appears to be the pressure of population which the growing obstructions in the way of emigration intensified. It would, perhaps, be more accurate to say that these were the reasons for the readiness with which any land offered was taken up; without such readiness the system could not have established itself. The cause, then, must be found in the early days of the movement, in the economic situation of the sugar industry necessitating all forms of economy; and the purchase of cane from peasant cultivation was found, as in Trinidad, to be more economical than direct production. But undoubtedly the movement was stimulated by the high prices realizable for land during and after the war when the high prices for sugar were reflected in cane prices. Prices of land of £100 to £125 became reasonably common, and, in one instance, £500 per acre is on record.

The economic effect of this development is disastrous. Partly this is due to the fact that large numbers of the purchasers lack agricultural experience and are not wholly dependent on cultivation for their livelihood. The Barbadian system of cultivation is an intensive one based on cane; even the smallest plot usually has half the area under cane. It is a system effective only under a high standard of cultivation which the type of proprietor is not usually prepared to employ, and, as often, unable to employ. It is not a system which lends itself to the control of disease, and its development has been marked by a steady increase of mosaic and borer in the cane, while the sweet potato weevil has, in places, become so abundant that the crop can no longer be grown. Difficulty of another order lies in the openings offered for praedial larceny.

There is no doubt that the evil inherent in the system has been aggravated by the enhanced prices paid for land, prices which could only be justified by an assurance, amounting to certainty, that they would be permanent. The consequence has been that the unit of area is commonly very small, rarely over ten acres and very frequently less than one. Of the 18,000 holdings in the island, no less than 77 per cent. are under one, and 95 per cent. under three acres. Behind the system is seen to lie the fundamental question of the economic holding. Skeete (6), whose report has been largely drawn on here, expresses the opinion that in normal times, an unencumbered plot of five acres of good land is the minimum economic area for a contented peasant, and then only if he devotes his whole time to cultivation. When the prices paid, and the instalment system which forms the basis of most of them, are considered, it is obvious that very few, if any, of the small holdings are economic at the present time of depressed prices, and it may be questioned whether any but a very few will become so, even when normal times return.

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UNIFORMITY TRIALS ON CACAO.

By E. E. Cheesman and F. J. Pound.

[*The West Indian Conference of Agricultural Officers held at the Imperial College of Tropical Agriculture in* 1930 *set up, under the chairmanship of the Director of Agriculture, Trinidad, a permanent committee known as the Field Experiments Committee "to consider for the guidance of Agricultural Officers of the Conference Colonies, methods of planning, executing and reporting field experimental investigations, and to devise in collaboration with these Officers methods of co-ordinating such investigations". At a later date, the chairman asked a sub-committee to deal with the specific problems of field experimentation with cacao. It appeared to this sub-committee that no problem was of more pressing urgency than that of the conditions to be observed when laying down experiments on existing plantations, and that the crux of this problem was the size of plot to be adopted, as determined by the degree of variability from tree to tree in the field. Yield figures, collected by the Trinidad Department of Agriculture over a number of years at River Estate, provided the necessary data, which could not be obtained in such complete form anywhere else in the world. This paper has therefore been prepared for the Field Experiments Committee and is published with the chairman's permission. Mr. Pound's note on the relation between total variance and annual yield is a corollary of the same statistical investigation.*]

Introduction.

Among the scientific advances of the last decade, none is of more importance to agricultural and horticultural investigators than the improvement of plot experiments. By the use in particular of the Latin Square and the system of Randomized Blocks to facilitate the Analysis of Variance, associated with the name of Fisher (3), a number of research workers have been able to demonstrate that from properly planned trials it is possible to extract an amount of information previously unapproached, with a precision subject to mathematical expression.

Inevitably the first advances have been made in temperate regions and with crops about which there is already a considerable volume of scientific literature. Workers in the Tropics, though fewer in numbers, have not been slow to grasp their significance, and the applicability of modern statistical methods under tropical conditions has already been the subject of much discussion.

In this connection it has been pointed out *inter alia* (1) that it is probably from the genetic point of view that the differences between tropical and temperate crops may most profitably be examined. Many of the major economic plants of the Tropics are trees, and almost without exception these orchard crops are highly heterozygous and consequently seriously mixed. Among them all, probably none is more heterogeneous than cacao, and if it can be shown that a fair degree of precision is attainable in field experiments on that crop, a similar result may reasonably be expected from the rest.

This question is apart from the consideration of methods of increasing genetic uniformity. It is almost certainly along the latter line that the greatest improvements will ultimately be effected, but in the meantime there are vast areas under heterogeneous plantation cacao, on which precise experimentation is badly needed.

Very fortunately the Department of Agriculture of Trinidad and Tobago has collected at River Estate individual yield figures from a large number of trees over a period of many years. By the kind permission of the Director, we have been allowed access to the records, and on certain analyses of them have been able to base the discussion which follows.

Variability in Plantation Cacao.

The figures available to us concern yield in pods per annum. The number of pods is not in itself an accurate measure of yield, since the pods of some trees give considerably more cacao than those of others. As an index of variability, however, the pod number serves our purpose very well, as it is itself the most variable component of final yield. It is quite unlikely that our conclusions would differ in their general outlines if they could be based on figures of final yield.

The annual production of pods by an individual tree in an ordinary cacao plantation may be anything from zero to about five hundred. The extremes among mature trees are naturally infrequent, but it has been recognized for some years, as a result of the work of Freeman (4) and de Verteuil (7), that some trees retain year after year the character of relatively heavy bearers whilst others are just as consistently poor bearers.

In order to obtain a numerical expression of tree-to-tree variability, we have calculated the standard deviation of several large samples from the River Estate records.

Table I.

Year.	No. of Trees.	Mean Yield per Tree.	Stand. Deviation.	Co-efficient of Variation.
1925-26	104	20.0	20.00	100.0
1926-27	541	42.1	40.46	96.1
1927-28	567	53.0	44.15	83.3

This extraordinary variability under practically uniform agricultural treatment must be attributed almost entirely to the interaction of three main groups of factors, which we will call

soil, constitution and age. The soil factors we take in a very wide sense to include all the influences bearing on the tree by reason of its topographical position in the field, including, for example, its position relative to shade trees, and constitution to include all the influences of genotype.

The age factor calls for the comment that it is no uncommon thing for fields of plantation cacao to contain trees of several ages, from one up to forty, fifty or even a hundred years old. This state of affairs is consequent on the custom of "supplying" gaps, where old trees have for one reason or another died out, with young seedlings. Where supplying has been done regularly, the field population is necessarily very heterogeneous with respect to age. Furthermore, it is the habit of the cacao tree to produce strong water-shoots (*chupons*) from the base of its trunk, and these are often allowed to replace the original trunk as the latter becomes senile. Thus, even among a number of trees whose root-systems are all the same age, there may be great variation in age of trunks and branches, which cannot be without its effect on yield. On these grounds, age is a most important factor in variability in the cacao field, as will appear.

The problem is, then, to determine the contribution to total variability of each of three sets of factors, and the extent to which each in turn may be eliminated when it is desired to compare treatments of any kind on plots of plantation cacao.

Methods.

Age may be eliminated at first by studying only fields uniform in that respect, and that course has been adopted.

Uniformity trials examined by the Analysis of Variance are then used to effect a partial segregation of the soil influences from the constitutional influences, the efficiency of the segregation depending largely on plot size.

There can be little doubt that the Latin Square is the best instrument for the purpose in hand, and the method adopted is to superimpose the same Latin Square, with varying plot size, on the yield plan of a selected field for each of four years and for the four years taken together. The field first selected is part of an established spacing experiment and contains trees uniformly about twenty years old, with very few "supplies".

The "treatments" are, of course, hypothetical, and the relative magnitude of the mean square due to "treatments" indicates the extent to which inherently good and inherently poor bearers are mixed in the field, the soil factor being largely eliminated in the "rows" and "columns".

At a later stage the age factor is re-introduced by transferring the same Latin Square to a field containing trees of all ages up to a hundred years, and making similar calculations.

Finally, an attempt has been made to estimate the value of previous records as a check on findings in any one year, and this has been done by an application of the method recently described by Sanders (5).

The Latin Square used throughout the analyses is here reproduced for reference (Fig. A), and by way of illustration of the lay-out, a diagram is also given of the block of trees used in the first uniformity trial (Fig. B).

FIG. A.

Latin Square.

A	C	B	D
C	D	A	B
D	B	C	A
B	A	D	C

Uniformity Trials with Age Constant.

(*a*) *Eighteen Trees per Plot.*

The first trial was placed on a block of trees spaced at 12 feet by 12 feet, forming part of the "Distance Planting Experiments" at River Estate. As shown in Fig. B, each plot consists of two rows, nine trees long, and the drains run lengthwise between the plots. The Analysis of Variance is set out for each of four years in Table II.

It is noteworthy how large a portion of the total variance is ascribable to "rows" and "columns", especially the latter. The variance due to "treatments" is low in every case, and though this is to be expected on account of the treatments being hypothetical, it is a most satisfactory result. It indicates that the mixing of genetic types in the field is sufficiently complete for a random sample of 72 trees, distributed in four plots of eighteen, to be fairly representative of the population.

The variance due to "interactions" enables us to estimate the probable success of a field experiment, such as a fertilizer trial, laid out on the site, and it is satisfactory to find that in three years out of the four, an average increase in yield of eight pods per tree as a result of treatment would be significant. This point is shown in Table X, and further discussed below.

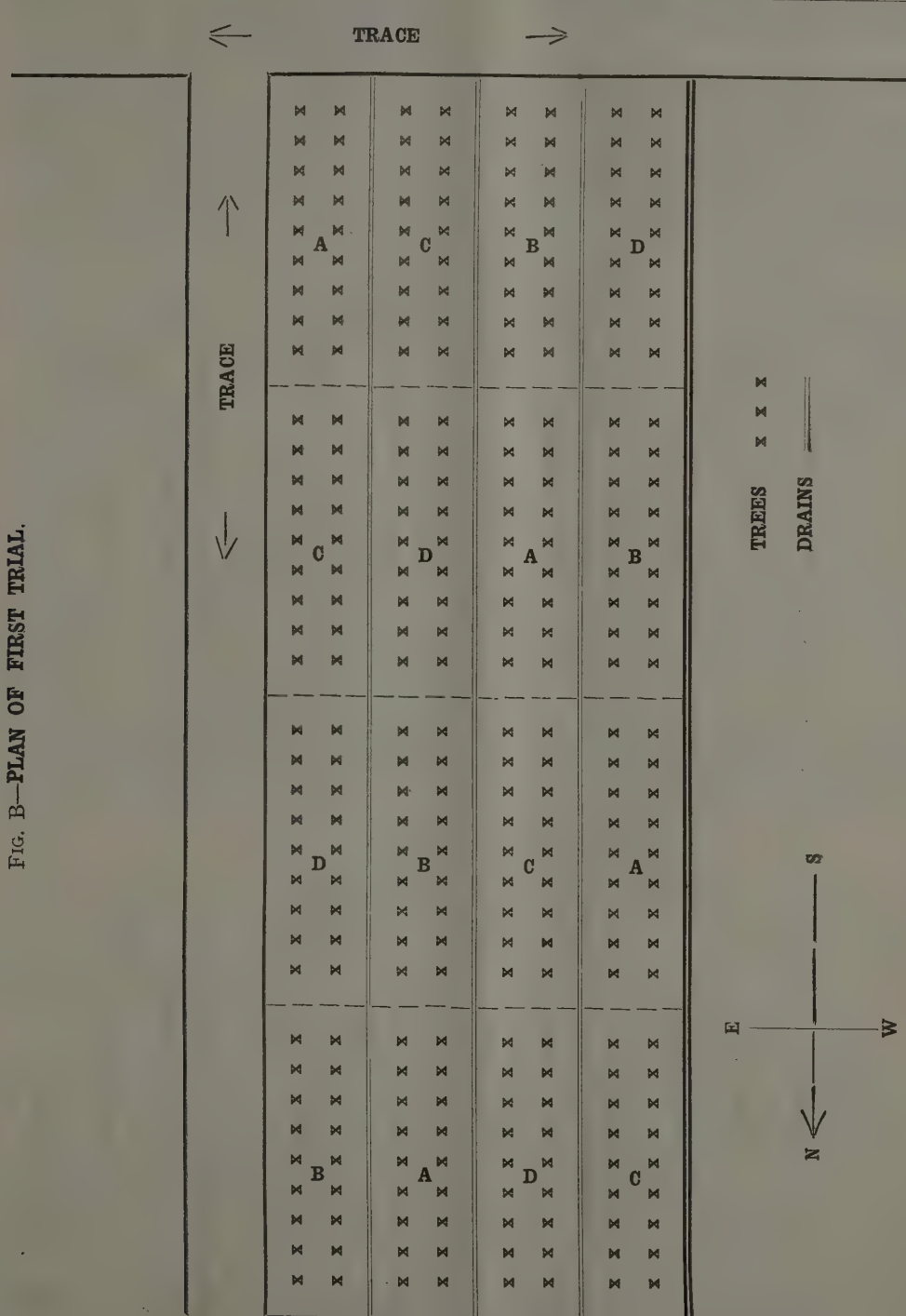

FIG. B—**PLAN OF FIRST TRIAL.**

(*b*) *Twelve Trees per Plot.*

The second trial was placed on part of the same block of trees, with the plot size reduced to 12 trees in two rows of six, and the Analysis of Variance is set out in Table III.

The most interesting feature of this table is that the total variance scarcely differs from that in Table II. The biggest contribution is again made in each year by "columns". The variance due to "interactions" is somewhat higher, but this is to some extent compensated by a markedly lower variance due to "treatments". Eden (2) has pointed out that since these two variances are "both independent estimates of random variance", we may "amalgamate the two sources and calculate a new mean square on the basis of the increased number of degrees of freedom". It thus appears justifiable for comparison to combine the sums of squares and divide by nine (degrees of freedom). When this is done in both Tables II and III, the value of the new estimate of random variance so obtained is of the same order in each case. Therefore, the precision obtained by the use of twelve-tree plots is very little less than that obtained by the use of eighteen-tree plots, and this conclusion is supported by examination of Table X.

Table II—Analysis of Variance.

EIGHTEEN TREES PER PLOT—AGE 18 YEARS.

	1926-27.				1927-28.			1928-29.			1929-30.		
	Degrees of Freedom.	Sum of Squares.	Mean Square.	½ $\log_e$.	Sum of Squares.	Mean Square.	½ $\log_e$.	Sum of Squares.	Mean Square.	½ $\log_e$.	Sum of Squares.	Mean Square.	½ $\log_e$.
Rows	3	83.0	27.7	1.6607	109.7	36.6	1.8000	23.0	7.7	1.0206	135.5	45.2	1.9056
Columns	3	146.0	48.7	1.9429	537.6	179.2	2.5942	417.0	139.0	2.4673	862.5	287.5	2.8306
Treatments	3	50.0	16.7	1.4072	31.7	10.6	1.1801	67.0	22.3	1.5523	41.5	13.8	1.3124
Interactions	6	330.0	55.0	2.0037	117.4	19.6	1.4878	108.0	18.0	1.4452	110.5	18.4	1.4562
Total	15	609.0	40.6		796.4	53.1		615.0	41.0		1150.0	77.3	

Table III—Analysis of Variance.

TWELVE TREES PER PLOT—AGE 18 YEARS.

	1926-27.				1927-28.			1928-29.			1929-30		
	Degrees of Freedom.	Sum of Squares.	Mean Square.	½ $\log_e$.	Sum of Squares.	Mean Square.	½ $\log_e$.	Sum of Squares.	Mean Square.	½ $\log_e$.	Sum of Squares.	Mean Square.	½ $\log_e$.
Rows	3	26.0	8.7	1.0817	287.0	96.0	2.2822	7.2	2.4	0.4378	215.0	72.0	2.1384
Columns	3	120.0	40.0	1.8445	418.0	136.0	2.4564	463.2	154.4	2.5195	618.0	206.0	2.6640
Treatments	3	41.0	13.7	1.3087	10.0	3.3	0.5970	13.2	4.4	0.7408	23.0	7.7	1.0206
Interactions	6	107.0	18.0	1.4452	143.0	24.0	1.5891	154.4	25.7	1.6233	240.0	40.0	1.8445
Total	15	294.0			858.0			638.0			1096.0		

(c) Six Trees per Plot.

The third trial was placed on part of the same site with plot size reduced to six trees in two rows of three, and the Analysis of Variance is given in Table IV. In this case records were used for an additional year.

The outstanding feature of Table IV is the great increase of total variance, and it is clear that this depends almost entirely on the two estimates of random variance, "treatments" and "interactions". The contribution represented by "rows" and "columns" remains almost unaffected by the decrease in plot size, but its distribution between rows and columns is much more erratic.

The loss of precision resulting from increase in random variance is serious, and is shown in terms of pods per tree in Table X.

(d) The Effect of Seasonal Variation.

In Table V the observations for the four years 1926-30 are combined for each plot size. The large contribution made throughout by "columns" is conspicuous, but is to be regarded as a result of the local peculiarity of the site chosen, and has no general importance. The contribution introduced by the new factor of "seasons" is considerable, and the fact agrees with common observation and general knowledge of the crop.

A point which appears to be new, and which calls for further investigation, is the indication that weather conditions in any given season affect not only the average yield but also the variability. Reference back to Tables II to IV shows that at all plot sizes the total variance was greatest in 1929-30, less in 1927-28, still less in 1928-29, and least in 1926-27. The average yields per tree over the whole field were greatest in 1928-29, less in 1929-30, and least in 1926-27 and 1927-28, these two years being the same. There is thus no correlation between yield and total variance in this field when the whole field is taken into account.

Summary for the "Soil" and "Constitution" Factors.

In Tables II and III in seven cases out of eight the sum of squares contributed by "rows" and "columns" is more than half the total. Whilst it is impossible to determine exactly how much of the difference between rows and between columns is due to soil heterogeneity and how much to genetic factors in individual trees, it may fairly be argued, from consideration of the small sums of squares contributed by "treatments", that the soil factors are mainly responsible. This conclusion is a strong argument for the use of the Latin Square in field experiments with cacao.

It is important to remember that the argument applies to plots, and not to individual trees, and that even the smaller plots have been excluded from it. The relative contribution of "soil" and "constitution" factors to the variability in yield *from tree to tree* still remains to be estimated, and until clonal material is available the estimation is likely to be impossible.

Granting, therefore, that the importance of constitutional factors in determining yield of individual trees is probably very great, its importance in determining yield of plots of 12 or more trees each seems to be small by comparison with that of the soil factors, which can be largely eliminated by a correct lay-out of plots.

Uniformity Trials with Age Variable.

A second series of trials was made by superimposing the same Latin Square as before on the yield plan of Field 5, River Estate, which

Table IV.—Analysis of Variance.

Six Trees Per Plot—Age 18 Years.

	1925-26.				1926-27.			1927-28.			1928-29.			1929-30.		
	Degrees of Freedom.	Sum of Squares.	Mean Square.	½ Log$_e$.	Sum of Squares.	Mean Square.	½ Log$_e$.	Sum of Squares.	Mean Square.	½ Log$_e$.	Sum of Squares.	Mean Square.	½ Log$_e$.	Sum of Squares.	Mean Square.	½ Log$_e$.
Rows	3	123.0	41.0	1.8568	64.0	21.3	1.5294	249.0	83.0	2.2094	33.0	11.0	1.1990	240.0	80.0	2.1910
Columns	3	454.0	151.0	2.5357	51.0	17.0	1.4166	243.0	81.0	2.1972	465.0	155.0	2.5217	568.0	189.3	2.6217
Treatments	3	406.0	135.0	2.4527	197.0	65.7	2.0926	293.0	98.0	2.2925	201.0	67.0	2.1024	60.0	20.0	1.4979
Interactions	6	435.0	72.5	2.1418	616.0	102.7	2.3158	301.0	50.0	1.9560	353.0	59.0	2.0388	1439.0	240.0	2.7403
Total	15	1418.0			928.0			1086.0			1052.0			2307.0		

Table V.

FINAL ANALYSIS—SIX TREES PER PLOT.

Due to	D.F.	Sum of Squares.			Mean Square.	½ $\log_e$.	Difference.
Rows	15	709.0			47.3	1.9283	—0.3266
Columns	15	1781.0			118.7	2.3884	0.1335
Seasons	4	886.5			221.6	2.7004	0.4455
Treatments	3	1157.0	483.0		161.0	2.5407	0.2858
Interaction of Seasons and Treatments	12		674.0	3817.0	90.9	2.2549	
Interaction of Parallel Plots	30	3143.0					
Total	79						

FINAL ANALYSIS—TWELVE TREES PER PLOT.

Due to	D.F.	Sum of Squares.			Mean Square.	½ $\log_e$.	Difference.
Rows	12	535.0			44.6	1.8989	0.3672
Columns	12	1619.0			135.0	2.4527	0.9210
Seasons	3	178.0			59.3	2.0413	0.5096
Treatments	3	87.0	26.0		8.7	1.0817	—0.4500
Interaction of Seasons and Treatments	9		61.0	705.0	21.4	1.5317	
Interaction of Parallel Plots	24	644.0					
Total	63						

FINAL ANALYSIS—EIGHTEEN TREES PER PLOT.

Due to	D.F.	Sum of Squares.			Mean Square.	½ $\log_e$.	Difference.
Rows	12	351.2			29.3	1.6888	0.1189
Columns	12	1963.1			163.6	2.5487	0.9788
Seasons	3	461.5			153.8	2.5185	0.9486
Treatments	3	190.2	94.5		31.5	1.7250	0.1551
Interaction of Seasons and Treatments	9		95.7	761.7	23.1	1.5699	
Interaction of Parallel Plots	24	666.0					
Total	63						

contains trees of all ages, from young "supplies" up to some more than a hundred years old. Three plot sizes were used, but as the available block was larger, the largest size was increased to 24 trees per plot, in two rows of twelve. Drains in this field run irregularly, but in general tend to cross the plots of the Latin Square. The figures used are from older records than those for the uniform age field.

The Analysis of Variance for three plot sizes is given in Tables VI to VIII, and the final analyses for the four years in Table IX. These Tables may be discussed together.

The total variance is on the whole slightly more in the largest plots of this series than it was in the smallest of the previous series, and it rises according to expectation with decreasing plot size.

The contributions due largely to soil heterogeneity ("rows" and "columns") are considerably higher than in the previous series, indicating that Field 5 was probably less uniform from the start, but their proportion to the total variance is markedly less.

The contributions due to "treatments" are generally high, indicating imperfect mixing of potential yielding power among the trees, but

Table VI.—Analysis of Variance.

TWENTY-FOUR TREES PER PLOT—AGE VERY VARIABLE.

		1921-22.			1922-23.			1923-24.			1924-25.		
	Degrees of Freedom.	Sum of Squares.	Mean Square.	½ Log$_e$.	Sum of Squares.	Mean Square.	½ Log$_e$.	Sum of Squares.	Mean Square	½ Log$_e$.	Sum of Squares.	Mean Square.	½ Log$_e$.
Rows	3	149.0	49.7	1.9530	876.0	292.0	2.8384	95.0	32.0	1.7329	64.0	21.0	1.5223
Columns	3	16.0	5.3	0.8339	1586.0	529.0	3.1355	558.0	186.0	2.6129	184.0	61.0	2.0555
Treatments	3	118.0	39.3	1.8356	2410.0	803.0	3.3442	293.0	98.0	2.2925	699.0	233.0	2.7255
Interactions	6	757.0	126.0	2.4182	865.0	144.0	2.4899	731.0	122.0	2.4020	755.0	126.0	2.4182
Total	15	1040.0			5737.0			1677.0			1702.0		

Table VII.—Analysis of Variance

TWELVE TREES PER PLOT—AGE VERY VARIABLE.

		1921-22.			1922-23.			1923-24.			1924-25.		
	Degrees of Freedom.	Sum of Squares.	Mean Square.	½ Log$_e$.	Sum of Squares.	Mean Square.	½ Log$_e$.	Sum of Squares.	Mean Square.	½ Log$_e$.	Sum of Squares.	Mean Square.	½ Log$_e$.
Rows	3	309.0	103.0	2.3174	548.0	183.0	2.6048	599.0	200.0	2.6492	571.0	190.0	2.6236
Columns	3	457.0	152.0	2.5120	831.0	277.0	2.8121	1489.0	496.0	3.1033	234.0	78.0	2.1784
Treatments	3	794.0	265.0	2.7898	785.0	262.0	2.7842	642.0	214.0	2.6830	946.0	315.0	2.3763
Interactions	6	379.0	63.0	2.0716	2538.0	423.0	3.0237	794.0	132.0	2.4414	733.0	122.0	2.4020
Total	15	1939.0			4702.0			3524.0			2484.0		

Table VIII—Analysis of Variance.

SIX TREES PER PLOT—AGE VERY VARIABLE.

	1921-22.				1922-23.			1923-24.			1924-25.		
	Degrees of Freedom.	Sum of Squares.	Mean Square.	½ Log$_e$.	Sum of Squares.	Mean Square.	½ Log$_e$.	Sum of Squares.	Mean Square.	½ Log$_e$.	Sum of Squares.	Mean Square.	½ Log$_e$.
Rows	3	893.0	298.0	2.8486	887.0	296.0	2.8452	596.0	199.0	2.6467	95.0	32.0	1.7329
Columns	3	180.0	60.0	2.0472	821.0	274.0	2.8066	1435.0	478.0	3.0848	1148.0	383.0	2.9741
Treatments	3	126.0	42.0	1.8689	3177.0	1059.0	3.4825	2070.0	690.0	3.2684	1395.0	465.0	3.0710
Interactions	6	1326.0	221.0	2.6991	813.0	135.5	2.4545	3035.0	506.0	3.1133	1120.0	187.0	2.6156
Total	15	2525.0			5698.0			7136.0			3758.0		

their actual magnitude is less striking than their lack of consistency. The figures both for "treatments" and for "interactions" are highly erratic, there being sometimes a significant "effect" of the hypothetical treatments, and at other times none.

The contributions of "seasons" in the final analyses are most interesting, indicating as they do on comparison with Table V., that climatic fluctuations have a much more serious effect on yield in fields heterogeneous for the age factor. This is difficult to explain and calls for further enquiry. It is also worthy of comment that in this series the order of the years with respect to total variance is not the same for all plot sizes, although 1921-22 shows least variance throughout and 1922-23 is generally high.

The one fact firmly established by this set of trials is the importance of the contribution made by the age factor to heterogeneity in the cacao field. The 24-tree plot is the best unit of the three tested, but the precision obtainable with it falls far behind that obtainable with an 18-tree plot of younger (and therefore more uniform) cacao.

Practical Conclusions from Uniformity Trials.

The object of the trials being to determine the practicability of statistically controlled field experiments, the results presented above have been translated in Table X into significant differences in terms of pods per tree per annum for P=0.05.

From Table X, an increase in yield due to treatment, on plots of 12 or 18 trees uniform for age, to be significant should be of the order of eight pods per tree. The other figures need not be considered further.

An increase of eight pods per tree appears small, but in terms of total yield it is large. The mean yield per tree on the 18-tree plots during the four

Table X.

SIGNIFICANT DIFFERENCES IN PODS PER TREE P=0.05.

Age Constant.

Year.	18 Trees Per Plot.	12 Trees Per Plot.	6 Trees Per Plot.
1926-27	12.82	7.34	17.54
1927-28	7.66	8.48	12.24
1928-29	7.34	8.76	13.29
1929-30	7.41	10.94	26.82

Age Variable.

Year.	24 Trees Per Plot.	12 Trees Per Plot.	6 Trees Per Plot.
1921-22	19.43	13.73	25.72
1922-23	20.73	33.58	20.14
1923-24	19.11	19.87	38.93
1924-25	19.43	19.11	23.66

years under review, fluctuated between 20 and 26 pods, so that an increase of eight pods means an increase of 30-40 per cent., and no real increase of less than 30 per cent. could be conclusively demonstrated.

Large as this figure is, there is little doubt that such increases are easily possible in a crop as responsive as cacao, and a wide range of useful experiments might be based on this level of significance.

On the other hand, there is obvious need for some methods of increasing precision and bringing the significant difference nearer to the ten per cent. order, which is easily possible with many temperate crops.

Increase of plot size may be dismissed with the remark that even our four by four square of 18-tree plots covers almost exactly an acre, without any allowance for the guard rows which would

Table IX.

FINAL ANALYSIS—TWENTY-FOUR TREES PER PLOT.

Due to	D.F.	Sum of Squares.			Mean Square.	½ $\log_e$.	Difference.
Rows	12	1184.0			99.0	2.2976	—0.1606
Columns	12	2344.0			195.0	2.6365	0.1783
Seasons	3	10664.0			3555.0	4.0881	1.6299
Treatments	3	3520.0	2124.0		708.0	3.2812	0.8230
Interaction of Seasons and Treatments	9		1396.0	4504.0	136.5	2.4582	
Interaction of Parallel Plots	24	3108.0					
Total	63						

FINAL ANALYSIS—TWELVE TREES PER PLOT.

Due to	D.F.	Sum of Squares.			Mean Square.	½ $\log_e$.	Difference.
Rows	12	2027.0			169.0	2.5650	0.0400
Columns	12	3011.0			251.0	2.7628	0.2378
Seasons	3	13843.0			4614.0	4.2185	1.6935
Treatments	3	3167.0	2448.0		816.0	3.3522	0.8272
Interaction of Seasons and Treatments	9		719.0	5163.0	156.0	2.5250	
Interaction of Parallel Plots	24	4444.0					
Total	63						

FINAL ANALYSIS—SIX TREES PER PLOT.

Due to	D.F.	Sum of Squares.			Mean Square.	½ $\log_e$.	Difference.
Rows	12	2471.0			206.0	2.6640	—0.0637
Columns	12	3584.0			299.0	2.8502	0.1225
Seasons	3	11621.0			3874.0	4.1311	1.4034
Treatments	3	6768.0	5336.0		1778.7	3.7420	1.0143
Interaction of Seasons and Treatments	9		1432.0	7726.0	234.0	2.7277	
Interaction of Parallel Plots	24	6294.0					
Total	63						

have to be added in any fertilizer trial. There are few places on cacao estates in Trinidad where an area of several acres of trees uniform for age could be selected without the introduction of complicating factors such as ravines, steep slopes or other topographical features which would be likely to overbalance any advantage from increased plot size. For such practical reasons the 18-tree plot is almost certainly the upper limit, and the 12-tree plot is preferable.

Replication of the square will increase the precision, and is too obvious a method to need discussion, but again there is a limit imposed by the amount of land taken up and the unwieldiness of a large experiment.

An alternative method which suggests itself is the use of several years' records to map variability in the field before treatments are applied. It was pointed out by de Verteuil as long ago as 1911 (6) that previous records of "natural yields" are highly desirable, if not essential, preliminaries to field experiments, and it is to that recognition that we owe the existence of the figures used in the present paper. We have, however, been able to treat the figures in a new way owing to the recent publication by Sanders (5) of a method which promises to be of very great assistance.

The Use of Previous Records.

Sanders points out that in comparing yields from the same plot in different years, although at first sight the simplest procedure would appear to be to take the difference between the two, statistically this may lead to a loss rather than a gain in precision. A gain may, however, be effected by means of the regression function between the two variables. Taking x as the yield of any plot under a preliminary uniformity trial (or its mean yield under more than one trial) and y as its yield in a subsequent experiment, he corrects the variance of y for x by using the equation

$$V_{yx} = V_y (1 - r^2_{xy}) = V_y - \frac{(\text{Cov.}_{xy})^2}{V_x}$$

where Cov._{xy} is the covariance between x and y, or the mean product of their deviations from their means.

This formula we have applied to the figures of Table II, treating 1929-30 as the "experimental year" and combining "treatments" and "interactions" under "random variance". Thence we get Table XI, showing that by combination of three years' previous records to correct the variance, precision in the experimental year has been doubled. Though no turning point occurs, it is probable from consideration of the later tables, that this is the maximum increase possible in this case.

To illustrate the effect of use of the regression on the complete analysis of variance, we may compare the analysis for y (1929-30 alone) with that for (y-bx) when x is the mean annual yield for the three years 1926-29.

Variance due to "treatments", mean of 1926-29 .. 9.57
Co-variance with 1929-30 .. 7.08

$$b = \frac{\text{Cov.}_{xy}}{V_x} = \frac{7.08}{9.57} = 0.7398.$$

This calculation uses up one degree of freedom and leaves five for "interactions".

	y—bx.			y from Table II.		
	D.F.	Sum of sq.	Mean sq.	D.F.	Sum of sq.	Mean sq.
Rows	3	102.2	34.1	3	135.5	45.2
Columns	3	232.2	77.4	3	862.5	287.5
Treat.	3	26.7	8.9	3	41.5	13.8
Inter.	5	40.6	8.1	6	110.5	18.4
Total		401.7			1150.0	

The Standard Error for the comparison of two treatment means is reduced from $\sqrt{9.2}$ to $\sqrt{4.05}$, which corresponds to a decrease in the number of pods necessary to demonstrate a significant difference from eight to five, or from 30-40 per cent. to 20-25 per cent. of the mean.

Unfortunately, the choice of 1929-30 as experimental year does not give an altogether representative result. From the same figures, if 1928-29 is chosen as the experimental year, the table of relative precision works out as follows:

Year.	V_{yx}.	Relative Precision.
1928-29	19.4	1.00
1927-28	15.7	1.24
1927-28+1926-27	19.8	0.98

Table XI.

	Random Variance.	Covariance with 1929-30.	V_{yx}.	Relative Precision.
1929-30	16.9	—	16.9	1.00
1928-29	19.4	+ 9.6	14.5	1.17
1928-29+1927-28	10.6	+ 9.8	10.8	1.56
1928-29+1927-28+1926-27	13.3	+11.6	8.2	2.06

There is now a slight gain in precision by the use of one year's records, but none when two years are included.

A somewhat similar result is obtained from the figures of Table VI, based on trees variable in age. When 1924-25 is chosen as the experimental year we get :—

Year.	V_{yx}.	Relative Precision.
1924-25	161.6	1.00
1923-24	37.3	4.33
1923-24+1922-23	93.2	1.73
1923-24+1922-23+1921-22	79.9	2.02

Correction by the yields of 1923-24 alone gives a fourfold increase in precision, yet inclusion of 1922-23 nullifies most of the advantage gained, whilst further inclusion of 1921-22 restores some of it. On reference to the actual yield figures we find that the yields from many individual trees in 1922-23 bore but little relation to those from the same trees in preceding and subsequent years, and this lack of correlation explains the result. It is perhaps significant that 1922-23 was an exceptionally good year from the point of view of yield. The point needs further investigation, but there is evidence that this is a general effect of a good season, especially on trees variable for age.

It was noted above that in the field of uniform age there appeared to be no correlation between yield and total variance, but in Table VI the order of total variances in the four years is exactly the order of the mean yields per tree, which were 45, 81, 58 and 64 pods respectively.

It seems reasonable to suppose, and there are data to support the view, that trees mature in age and inherently good yielders, have a yielding capacity far above their normal performance. Thus, in a favourable season they draw farther ahead of the younger supplies and the inherently poor yielders than in a bad year, increasing the total variance in the field, and reducing the correlation between their own performances in consecutive years. Hence either an exceptionally good or an exceptionally bad year from the point of view of yield, will be an unfavourable year to use for "correcting" the variance in an average year.

On the same plots, when 1923-24 is chosen as the experimental year, there is a progressive increase in precision up to a maximum, using three years' records, of nearly eight times.

Year	V_{yx}.	Relative Precision.
1923-24	114.0	1.00
1922-23	71.0	1.61
1922-23+1921-22	30.4	3.75
1922-23+1921-22+1920-21	14.5	7.86
1922-23+1921-22+1920-21+1919-20	18.1	6.30

It will be noted that the control of 1922-23 on 1923-24 is not nearly so good as that of 1923-24 on 1924-25, and this is according to expectation. Also, there is no advantage in going beyond three years for previous records.

It is also in accordance with anticipation that the advantage of previous records, in a case where they are really valuable, is much greater for trees variable in age than for trees uniform in age. There is more scope for improvement in the greater total variance, and furthermore, the variability introduced by the age factor is especially likely to be eliminated by application of the correlation between consecutive years.

Even so, the precision obtainable with the trees variable in age is still less than that possible when age is uniform, and trees of uniform age should always be chosen when possible for field experiments.

The Use of Biennial Averages.

There is a noticeable tendency, particularly in old fields, for a good cacao crop in one year to be followed by a poor crop in the next, and *vice versa*. This suggests that combination of consecutive years in pairs might increase the precision obtainable by the use of previous records, and the figures have been worked out for the data from Table II.

Analysing the variance of the mean yields in the years 1928-29 and 1929-30 taken together, with and without the regression on the means for 1926-27 and 1927-28 taken together, we obtain Table XII.

	Without Regression			With Regression.		
	D.F.	Sum of sq.	Mean sq.	D.F.	Sum of sq.	Mean sq.
Rows	3	28.5	9.5	3	26.5	8.8
Columns	3	649.0	216.3	3	623.9	208.0
Treat.	3	41.5	13.8	3	43.8	14.6
Inter.	6	64.0	10.7	5	60.8	12.2
Totals	15	783.0	52.2	14	755.0	53.9

Comparing with the analysis for 1929-30 taken alone in Table II, it is evident that the combination of two years in this case gives a very definite advantage. On the other hand, increased precision having been obtained in this way, the regression no longer helps, but owing to the elimination of one degree of freedom from Interactions, actually decreases precision somewhat. Thus, in this particular case an increase in precision such as might be expected from the use of two years' previous records has been obtained by the simpler expedient of combining records for two consecutive years, and this method may well be worth further exploration.

General Summary.

From uniformity trials on cacao based on data accumulated at River Estate by the Trinidad Department of Agriculture, it may be concluded that:—

(1) In cacao reasonably homogeneous with respect to age, field experiments on a Latin Square lay-out with 12 to 18 trees per plot may be expected to demonstrate differences due to treatment of the order of 30 per cent.

(2) Under similar conditions the use of two or three years' previous records of natural yield, applied by Sanders' method, may double the precision.

(3) Under some circumstances the combination of consecutive years in pairs may reduce the standard error as much as the use of regression.

(4) In cacao heterogeneous for age, field experiments cannot be recommended unless previous records of natural yield are available.

(5) The use of records for three years previous to the experiment may increase precision as much as eightfold, and thus bring within the bounds of practicability, experiments on cacao heterogeneous for age. The precision, however, still remains below that obtainable with cacao uniform in age.

(6) The value of previous records varies with circumstances, and cannot be stated in general terms, because the inclusion of an abnormally good or an abnormally bad year among them may result in a loss rather than a gain in precision.

Acknowledgment.

The writers wish to convey their thanks to Mr. P. E. Turner for his interest and frequent assistance in the statistical work.

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THE FRUITFULNESS OF CACAO.

The Significance of the Relation between Total Variance and Mean Annual Yield.

By F. J. Pound, B.Sc.

The analysis of natural yield carried out on a number of cacao trees at River Estate suggested that there may be a relationship between the quantity called the "Total Variance" and the actual yield in pods under certain conditions.

The analysis was conducted as a series of uniformity trials on two distinct fields differing chiefly in the age of the trees concerned. In the first case where none of the trees were old, the oldest being less than twenty years, there was distinctly no correlation between these two quantities. In the second where the trees were variable for age, the correlation was distinctly not good except in one year when the order of the values of natural yield agreed exactly with the order of the variance.

The fact that when older trees are included in the analyses, there is a possible correlation between yield and variance prompted the analysis of a larger block of trees. The complete block of 567 trees which comprise the "partial shade" portion of a shade experiment at River Estate was used and the separate annual variances for the seven years from 1921-22 to 1927-28 inclusive, were estimated and correlated with the actual mean yields per tree.

The block of seven years chosen was quite arbitrary, occurring approximately in the middle of a period of years over which the Department of Agriculture were taking natural yield records on these trees.

Results.

Table 1 shows the mean yield for each year and the total variance. In addition, the number of trees giving less than 21 pods in the years concerned, is shown in Column 4. These trees are taken to be poor bearers in these particular years. Column 5 shows the number of trees which yielded more than 140 pods. These are considered to be the good bearing trees.

The figures show that there is a very significant positive correlation between the yield in each year and the total variance. The correlation is so high ($r = 0.97$) that it would occur by chance much less frequently than once in a hundred trials.

The correlation between mean yield and the number of good bearing trees is almost absolute ($r = 0.99$).

At the same time there is a very significant negative correlation ($r = -0.94$) between the mean annual yield and the number of poor bearing trees.

(N.B.—The average yield per tree in Trinidad is said to be 12 pods.)

Table I.

Year.	Mean Yield.	Total Variance.	No. of Trees giving less than 21 pods.	No. of Trees giving more than 140 pods.
1921-22	45.0	1579	172	19
1922-23	84.7	4749	85	99
1923-24	58.1	2606	141	38
1924-25	65.0	3103	121	56
1925-26	51.9	2762	185	31
1926-27	61.6	3051	126	48
1927-28	48.1	1949	178	26
"r"	—	+.97	−.94	+.99
"σ"	—	—	33.75	24.86
C. V.	—	—	23.4	55.2

P=0.01 n=5 r=0.87

The economic significance of these relationships seems worthy of comment. Variance is an expression of the shape of the yield distribution curve. If the variance is small, it means that the curve rises rapidly to a maximum and falls steeply after passing that maximum. If the variance is large, the curve does not rise so rapidly, the maximum is lower and the rate of falling off is less. In other words an increase of variance accentuates the ends of the curve at the expense of the middle portion.

In terms of cacao trees, a field in which good bearers and poor bearers together form a large percentage of the population, will give a yield distribution curve with a large variance. On the other hand, for a field in which nearly all the trees are medium bearers the yield distribution curve will have a small variance.

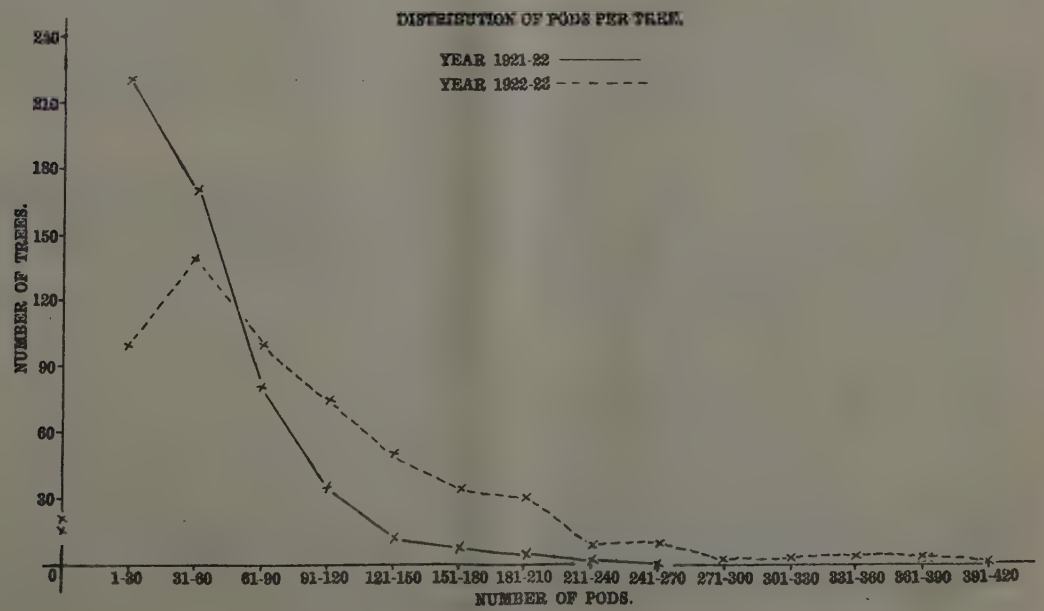
Broadly then, in a poor year the tree population is of the latter type and in a good year of the former type. The effect of a good season is to increase the number of good bearers, while the negative correlation between yield and the number of poor bearers bears out the fact shown in Table I, Col. 4, that the number of poor bearers is actually decreased. That is, practically all of the increase in variance takes place in the upper tail of the curve.

The actual yield frequency curves for 1921-22 (the worst year of the seven) and for 1922-23 (the best year) illustrate the point perfectly (*see* diagram).

Further, the increase at the upper end is much greater than the decrease at the lower end. In 1922-23 the number of poor bearers was halved compared with 1921-22, but the number of good bearers increased five-fold.

The situation may usefully be regarded from the point of view of the discrepancy in any year between the potentiality of a tree and its actual performance. Granting that in a good year the potentiality of each tree will be more closely approached by performance than in a poor year, it appears that in potentiality, the heavy bearers are even more superior to the light bearers than they appear in average performance.

In the consideration of cultural and manurial treatments this finding is of great importance, for it is only reasonable to suppose that the trees responding most markedly to better weather will be the ones to respond most profitably to better treatment. Additional emphasis is thus to be laid on the importance of the heavy bearers, relatively few in the average field, as the constituents of the crop which make—or should make—the profit.



Since the relationship between total variance and yield does not show in young trees, it follows that the bulk of the really good bearing trees are the older ones. This introduces a complication, for the older trees, being larger than younger ones, are able to support a bigger crop. Thus there are two factors which determine yield, the first is the actual inherent capacity to yield and the second is the size of the tree. To illustrate the latter factor the 102 trees on an observation plot at Caura were classified in January, 1931, into four categories dependent on size (and approximately age). The crop from January to June of that year showed distinctly that the older and larger trees produced on the average more pods than the smaller and younger ones. The following table shows that the correlation between yield and size (or age) is very close.

Table II.

Age.	No. of Trees.	Mean Yield.
Very Young	11	0.1
Young	15	10.3
Old	61	41.5
Very Old	15	87.5

The eleven very young trees are all supplies not yet old enough to produce a pod under estate conditions.

In selection, the annual yield in pods alone is not sufficient. The more important point is the number of pods produced per unit area of land, since several of the high bearing trees known to the writer overshadow at least six neighbours and the latter consequently produce no crop.

Summary.

1. It is found that in fields heterogeneous for type and age there is a very significant positive correlation between the mean annual yield in pods per tree and the total tree-to-tree variance.

2. On statistical grounds this must be due to the fact that in good years the yield of good bearing trees draws far away from the yield of poor bearing trees. The proportionate increase of crop may possibly be about the same for all trees but in any case good bearing trees have a greater capacity for increase of yield than poor bearing trees.

3. This contention is supported by the number of good and poor bearing trees occurring each year.

4. There are two factors responsible for capacity to yield, the size and age of the tree, and its inherent capacity to produce fruit. Therefore, in selection on the basis of yield of pods alone, attention must be paid more to the number of pods produced per unit area of land than to the actual number of pods produced by the tree.

A VARIETY TEST ON SUGAR-CANE.

By R. Cecil Wood, M.A. (Cantab.), Dip. Agric.

I. Statement of Problem.

It is held by some that the future of sugar production in Trinidad is largely bound up with the possibility of growing *thin canes*, since such canes, though they may never produce as much sugar to the acre as a heavy crop of 'noble' canes, can yet, owing to their hardy constitution, be grown at a much smaller cost, and under conditions which 'noble' canes would not tolerate.

An experiment was therefore started on the College Estate by the Agricultural Department of the College, to test some of the most promising thin canes, against the only one which is at present grown to any extent in Trinidad, namely, Uba. Seven other varieties have been grown in comparison with this cane, and the results of the first year's cropping are described below. It is proposed to continue the plots for three or four years.

II. Procedure.

Area.—The field chosen for the experiment was a deteriorated alluvial yellow loam, lying on the dividing line between the swamp and lagoon alluvial soils to the south, and the hill detrital soils to the north. This type of soil is acidic in reaction and in general of low fertility, but this field had been limed and otherwise fairly well treated, and has grown a fair crop of canes. Though, like most of the College land, it has only recently been cleared, and is in consequence lacking in uniformity, it is hoped that the lay-out of the experiment has largely eliminated the effects of this irregularity.

Manure.—The land received a dressing of seven tons of ground limestone to the acre in April, 1930. A very heavy crop of sunn hemp (*Crotalaria juncea*) was grown after this, and was cutlassed and ploughed under in August that year. In September, a dressing of 12 tons of pen manure was applied.

Planting.—The canes were planted in September and October, 1930, in shallow trenches, five feet apart, and four feet apart in the row, and were reaped in April, 1932, when 19 months old.

Cane Varieties.—The following varieties were grown:—

P.O.J. 36	P.O.J 826	Co. 281
P.O.J. 213	P.O.J. 2878	M. 36
P.O.J 234	Co. 213	

Experimental Lay-out.—Each plot was 7 rows in width (35 feet), and each row contained 22 stools (88 feet), so that its area was 3,080 square feet, or 0.07 acre. There were 4 randomised blocks with 8 plots in each block. Each variety occupied one plot in each block, with the exception of Co. 218 and M. 36, which, on account of shortage of planting material, only occupied 2 plots each.

III. Experimental Data.

These are tabulated below for weights of cane and calculated yields of sugar :—

Table I.

YIELDS OF CLEANED CANE IN CWTS. PER PLOT, LESS 60 cwts.

Block.	P.O.J. 2878.	Co. 213.	M. 36.	P.O.J. 36.	P.O.J. 213.	Uba.	P.O.J. 826.	Co. 281.	P.O.J. 234.	Total. (1)
A	17.00	23.00		1.25	− 6.75	−15.50	−14.25	−17.00	− 34.75	−30.00
B	40.75	18.75	−18.50	4.50	− 5.75	−12.00	−20.50		− 21.75	4.00
C	22.25	22.25		14.00	− 5.50	−15.25	−11.75	−19.00	− 30.75	− 4.75
D	31.00	16.75	+31.75	2.75	−14.50	−11.00	− 8.75		− 21.00	− 4.75
Total	111.00	80.75	26.50(2)	22.50	−32.50	−53.75	−55.25	−72.00(2)	−108.25	−35.50

General Mean −1.27

YIELDS OF SUGAR IN CWTS. PER PLOT. LESS 4 CWTS.

Block.	P.O.J. 2878.	Co. 213.	P.O.J. 36.	P.O.J. 213.	M. 36.	Co. 281.	P.O.J. 826.	Uba.	P.O.J. 234.	Total. (1)
A	2.1	2.1	.7			− .5	− .4	− .1	−2.0	2.4
B	3.3	1.4	.9	1.3	−1.8		−1.7	.1		5.3
C	2.2	− .1	.9	1.2		.2		− .5	−1.7	2.0
D	3.7	1.9	.5	− .8	3.1		.4	−1.5	− .9	3.3
Total	11.3	5.3	3.0	1.7	2.6(2)	− .6(2)	−1.7	−2.0	−4.6	13.0

General Mean 0.46.

(1) Omitting M.36 and Co.281.

(2) Figures doubled to make them comparable.

Table II.

Analysis of Variance.

(*a*) *Yields of Cane.*

Due to	Degrees of Freedom.	Sum of Squares.	Mean Square.	$\frac{1}{2}\log_e$. (Mean Square).
Blocks	3	92.30	30.76	—
Treatments	6	9345.93	1557.65	2.524
Error	18	765.98	42.55	0.724
Total	27	10204.21	—	1.800

Standard Error of a Single Plot = $\sqrt{42.55}$ cwts.

Standard Error of Total of Four Plots = $\sqrt{42.55 \times 4} = 13.05$ cwts.

or 5.3 per cent. of 234.9 cwts., the Mean Yield for Four Plots.

(*b*) *Yields of Sugar.*

Due to	Degrees of Freedom.	Sum of Squares.	Mean Square.	$\frac{1}{2}$ $\log_e$. (Mean Square).
Blocks	3	0.98	0.33	
Treatments	6	42.95	7.16	3.286
Error	18	3.47	0.18	1.445
TOTAL	27	57.40	—	1.841

Standard Error of a Single Plot = $\sqrt{0.18}$ cwts.

Standard Error of Total of Four Plots = $\sqrt{0.18 \times 4}$ = 0.848 cwts.

or 4.7 per cent. of 17.84 cwts., the Mean Yield for Four Plots.

Table III.

Variety.	Yield per Acre, Cane.	Per cent. on Uba.	Order of Merit.	Yield per acre, Sugar.	Per cent. on Uba.	Order of Merit.
	Tons.			*Tons.*		
P.O.J. 2878	57.0	189	1	4.43	195	1
Co. 213	52.1	172	2	3.46	152	2
M. 36	43.2	143	3	3.02	133	4
P.O.J. 36	42.6	141	4	3.09	136	3
P.O.J. 213	33.7	112	5	2.87	126	5
Uba	**30.1**	**100**	6	**2.27**	**100**	8
P.O.J. 826	29.8	96	7	2.32	102	7
Co. 281	27.2	90	8	2.50	110	6
P.O.J. 234	21.3	71	9	1.85	81	9

The results are certainly significant; the differences due to variety are practically the same in each case, whether judged as cane or as sugar. The one per cent. point, or one chance in a hundred, in Fisher's Table of *z* is, for this experiment, 0.6950.

Final Analysis.—The mean acre yields of the varieties, expressed both as weights of stripped cane and as 96° sugar* are given below. Columns are also given, showing their relation to Uba, expressed as 100.

IV. Discussion.

A full discussion of the results is not needed at this stage, as the experiment is to run for three harvests or more, and it will only be at the end of that time that it will be possible to say whether any of these canes is likely to supplant *Uba*. On the single harvest figures, it is evident that *Uba* is inferior, both in weight of canes and still more in weight of sugar, to most of the varieties tried. It is also evident that *P.O.J.* 2878 is a cane of outstanding merit, with a wonderful yield of cane per acre, and a fair quality.† As compared with *Uba*, it gives 89 per cent. more cane, but 95 per cent. more sugar, an improvement of 6 per cent. In quality, it is beaten by *P.O.J.* 213, which improves 14 per cent., and *Co.* 281, which as compared with *Uba*, gives 10 per cent. less weight of cane, but 10 per cent. more sugar.

* These are based on analyses kindly supplied by the Sugar Technology Department of the College.

† This cane is usually considered to be of very poor quality. It is not up to the standard of the better seedling canes, but it is possible that the correct time for planting, under Trinidad conditions, has not yet been ascertained; experiments on this point are being initiated.

It is not possible to give either general or particular costs of harvesting these canes. The canes lodged badly, and the labour of separating the plots was one of great difficulty. Furthermore, labourers will not ordinarily cut canes of this class without having them burnt first, and to do this would have needed a much larger organisation for cutting, carting and sampling all the plots within a short time, than it was possible to obtain. There are, however, very considerable differences shown by the varieties in this important respect. *P.O.J.* 2878 is outstanding in ease of reaping, and it was found that a man could cut about 2½ tons a day, even though a considerable quantity had to be left in the field as being too immature to be loaded. *Uba* was definitely the worst; very trashy and difficult to cut, so much so, that if the canes were to be properly cleaned, 12-15 cwt. were all that a man could reap. Another easy cane to harvest was *P.O.J.* 36; others noted as particularly difficult were the two Coimbatore canes, and *P.O.J.* 234, either from their small size, or their abundant trash.

REVIEWS.

Cacao.

By Dr. C. J. J. Van Hall. pp. 514, price 28*s*. *Macmillan & Co.*

The first edition of this book, although published seventeen years ago, will always remain a classic, famous for its practical value to the cacao planter. It consisted of nothing less than a clear exposition of everything related to cacao culture that was then known, together with concise notes of local methods employed in all the well known cacao producing countries.

The second edition retains those same good qualities which distinguish the first, together with a number of additions which bring the work practically up to date.

One of the most important of these is the discussion of manuring in Chapter VI. The old-time method of comparing one manured plot with one control plot did not and could not be expected to give any significant results. The author has made it quite clear that in future, advantage must be taken of scientific methods of plot lay-out and analyses if any benefit is to be derived from experiments of this sort.

Another good point is the emphasis laid on selection of planting material. Yields can be increased and also made more uniform if a little trouble is taken by the planter in selecting seed rather than sowing anything that comes to hand. It is not difficult to label one or two trees which are known by repeated observation to be good in some respect and to supply from the best of them.

The Chapter on "Diseases and Enemies" has been very much enlarged. It is particularly refreshing to find the author adopting the attitude that in many cases a disease is only the outward and visible sign of an inward physiological trouble. A tree in poor soil, not properly shaded, drained or cared for is more liable to succumb to infection than is a healthy tree. This not new, but little practised point of view, throws light on the steps which should be taken to effect a cure. It is also interesting to note that a number of trees in Ecuador have been found which seem to be immune to Witchbroom disease.

It would have been interesting to know a little of the methods by which the different cacao producing countries have met the abnormal decline in prices during the last few years. However it is hoped that this problem, very acute at present, will prove to be purely ephemeral.

Perhaps it is unfortunate in some respects that, after waiting seventeen years, the author should have revised his work at a time when the cacao producing countries of the British Empire are devoting so much research to the cacao crop. Already in Trinidad a number of facts have recently come to light which help to explain the failure of the earlier manurial experiments. Further, the author's principles of selection, shared by others, have even now been put into practise and the list of "good" trees is rapidly growing.

In Brazil also, a certain amount of research is being commenced so that during the next few years a good deal of fresh information should be forthcoming.

Nevertheless, this book will, for many years be regarded as the practical guide of the cacao planter, and the man who applies the principles therein to the local conditions of his estate, will not stray far from the path of success.

F. J. P.

* * *

The Donnan Equilibria.

By T. R. Bolam, London. *G. Bell & Sons*, 1932. pp. 154, Price 9*s*.

Although this book is not directly concerned with any particular branch of the Agricultural Sciences, it deals with a theory which has been successfully applied in explaining certain phenomena exhibited by colloidal materials of agricultural importance. For example, the Donnan equilibrium provides a method for the measurement of the adsorption of ions by particles in inorganic colloidal systems, included among which are soils. It also explains some of the properties of proteins and of biological systems such as blood. It may be applied to the theory of enzyme action, as well as the phenomenon of swelling in gels, such as gelatine and cellulose. It finds application in the processes of leather manufacture and dyeing, and in certain physico-chemical processes such as cataphoresis, viscous behaviour, and distribution of ions within gels.

The subject is treated throughout in a mathematical and graphical manner, and is clearly presented in simple language. The book may be highly recommended to advanced students of the more academic branches of biological and agricultural chemistry.

F. H.

SUGAR NOTES.

Compiled by the College Department of Sugar Technology.

The Fermentation of Final Molasses. *H. E. Cruz Monclova.*

A list is given of the products obtained by the industrial fermentation of cane juice and cane molasses, with brief mention of the organisms and principal methods of obtaining the different products. The yields obtainable are given as follows (in percentages): Acetic acid, 50-55 per cent.; proprionic acid, 30-40; butyric acid, 30-40; lactic acid, 90; citric acid, 70; oxalic acid, 70; fumaric acid, 60; gluconic acid, 50-55; kojic acid, 25; ethyl alcohol, 4; butyl alcohol, 14; acetone, 7; glycerine, 25; ethyl alcohol, 30; acetaldehyde, 10.

The kojic acid, which appears in this list, is a derivative of gamma-pyrone, which is related to the flavone group. Production of this acid on a large scale would make possible the use of molasses or cane juice in the manufacture of the flavone (yellow) dyes. The organisms used are various species of *Aspergillus*: *A. albus, A. candidus, A. nidulans, A. flavus, A. oryzae.* The sugar solutions are inverted, and fermentation is carried out in shallow tanks, or aeration is employed. The yield is 20 to 25 per cent. on the weight of sugar employed, but this may perhaps be improved when the process has been studied in greater detail.—(*Facts about Sugar,* Vol. XXVII, No. 7, July, 1932.)

* * *

Electricity in Sugar Factories.

After discussing the various advantages of the electrification of the cane factory, Frank P. Bell in a paper read at the Second Conference of the Queensland Society of Sugar Technologists, remarked that there is now no difficulty in the way of complete electrification. An electric drive is available for every operation from the winches hauling the cane to the carrier to the laboratory. In the past, say 15 years ago, the difficulty was with the rolls and carrier, but now these can be driven by a slip ring induction motor.

A method used in Great Britain for driving heavy units (in steel rolling plants) needing a strong starting torque, is known as the Ward-Leonard system. It consists of a motor generator set connected to a D.C. motor, the motor being either A.C. or D.C. according to the supply available. Driven at 750 revs. per min., the D.C. generator is connected without switch-gear to the motor driving the rolls. This motor running at 300 revs. per min. is geared down through double helical machined gears to 40 revs. per min. at the rolls. As to the cost of the equipment, initially this is rather more than for a steam drive; but the reliability, the power to start up under heavy loads, quick stop and reverse, the quiet running, the saving in lubrication, and the economy of having a central power-house drive for the whole mill constitute a compensation.

Another method is to convert a portion of the available A.C. power into D.C. in the power-house and drive the rolls by D.C. motors, easily regulated by a shunt regulator. This method was installed at the Kedawoeng factory, Java, and a regulation of 40 to 50 per cent. was obtained. A suitable equipment for a sugar factory is as follows. Power house: three 500 K.V.A., three-phase 400 volts turbo-generators. Factory: motors, three or four Ward-Leonard sets or D.C. motors for the rolls; squirrel cage motors for all stations up to 30 h.p. and slip ring induction for larger sizes. Lighting: carefully done to avoid shadows and provide sufficient light without glare. Laboratory: ovens, stills, hot plates and heaters. Electric power generation for public consumption is a very profitable and easily exploited method of utilizing surplus bagasse, the costs of generating during crushing amounting only to one-eighth penny per unit, which lowers the average of the whole year.—(*Int. Sugar Jr.*, Vol. XXXIV, No. 398, p. 63.)

* * *

Bagasse Board in Hawaii.

We learn from "*Facts about Sugar*", in the issue for July, 1932, that a large plant for manufacturing insulating board from bagasse was formally opened for operation in April this year at Hilo, Hawaii. This project represents an investment of over two million dollars, and the factory will produce annually some one hundred million square feet of building material. The company controlling the venture is known as the Hawaiian Cane Products Ltd., and is represented by owners of sugar factories responsible for ninety-five per cent. of the Hawaiian cane crop. The plant will consume ten per cent. of the total bagasse supply of the Islands. The processes of screening, storing and handling the bagasse are very ingenious and efficient. Cooking is carried out in four 14-foot rotary digesters; refining by grinding, thickening and washing follows automatically, after which the stock is mixed with rosin-size emulsion, diluted to 0.75 per cent. consistency, and then formed in a vacuum machine. The boards are next lightly pressed in a mill comprising five pairs of rubber-coated rollers, and cut whilst wet into suitable lengths by means of a high-speed machine saw. They are finally dried in an eight-decker dryer, 340 feet long.

* * *

Chemical Treatment of Low-Grade Massecuites.

In an article which appeared in the July 1932 issue of *The International Sugar Journal*, H. L. Grogan, of Caroni Estate, Trinidad, describes experiments conducted to determine the relative efficiency of slaked lime (calcium hydroxide) and of soda ash (sodium carbonate) in the treatment of low-grade blank-boiled molasses-massecuites, in order to reduce losses by inversion and to aid curing. It was found that calcium hydroxide gave a superior yield of sugar of a paler colour, and that this difference in yield is mainly due to the lesser retarding effect of calcium hydroxide on sucrose crystallisation.

IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

COLLEGE NEWS BULLETIN

OCTOBER, 1932.] [No. 4.

COLLEGE NEWS.

Mr. G. Evans, Principal, accompanied by Mrs. Evans, sailed for England on leave by the s.s. *Bayano* on 27th June.

* * *

A meeting of the Agricultural Society was held at the College on Thursday, 11th August, at which Professor Wood read a paper on Tobacco.

* * *

An Historical Society has recently been started in Trinidad. Mr. C. Y. Shephard, Professor of Economics, is the Hon. Secretary and Treasurer.

* * *

A new circular road, running from the St. Gill Halt along the railway to the Curepe crossing, is, we understand, to be called " Evans Road ".

* * *

We have heard with pleasure that a daughter has been born in England to Mrs. Paterson, the wife of Mr. D. D. Paterson, Lecturer in Agriculture.

* * *

Dr. H. R. Briton-Jones, Professor of Mycology and Bacteriology and Dean of the College, went on leave on 14th July, sailing for England by the s.s. *Colombie*.

* * *

Mr. J. B. Hutchinson, Assistant Geneticist at the St. Augustine Cotton Research Station, and Mrs. Hutchinson, returned from England after four months leave, by the s.s. *Carare* on 21st August.

* * *

We have pleasure in announcing the birth of a daughter to Mrs. Myers, the wife of Dr. J. G. Myers, Entomologist in charge of the Biological Control of Insect Pests in the West Indies.

* * *

Among recent visitors to the College were : Mon. Charles Laparra, Ingénieur Agronome (I.N.A), Martinique ; Mr. C. L. A. Meilliac, Port-of-Spain ; the Misses Phyllis and Vera Hollingdrake, the Bonar Law Memorial College, England ; Miss Gladys M. R. Brough, B.A. (Lond.), University of London ; Mr. A. A. Revell, California ; Mr. G. G. Mason, Jnr., Representative of the Pan American Airways, Cuba, and Mrs. Mason.

Mr. S. A. Schouten, one of the third year Diploma students, during the 1931-32 session, has acted as the College Overseer for two months during the absence of Mr. Seignoret, the permanent incumbent.

* * *

We offer our heartiest congratulations to Mr. J. A. McDonald, Cacao Research Chemist at the College, who was married to Miss Thelma Seheult, daughter of Mr. and Mrs. L. G. Seheult of St. Augustine, on 9th July.

* * *

The College Department of Agriculture has decided that in future all the farm fields will be known by numbers instead of letters. No. 1 is the field next to the Botany Department's land, and No. 34 is the southernmost triangular field across the road.

* * *

Dr. J. G. Myers and Mr. J. D. E. F. Vezey-Fitzgerald left Trinidad for Brazil on 18th June by airplane, on a search for parasites which might be of use in Trinidad for the control of the sugar-cane froghopper. The expedition is expected to extend over a period of at least six months.

* * *

It was noticed one day recently that most of the College Staff appeared to be wearing their best clothes. The cause has now been discovered in a Jumble Sale, in aid of the Child Welfare League, which Mrs. Evans organised before she left for England. After all, clothes that one is wearing can hardly be sent to the Sale. Safety first !

* * *

Mr. F. Hardy, Professor of Chemistry and Soil Science, left Trinidad on 21st August by the s.s. *Carare*, on a visit to Jamaica to confer on soil matters with Mr. H. C. Croucher (formerly lecturer in Chemistry and Soil Science at the College, now Government Agricultural Chemist in Jamaica). The visit is the outcome of an official invitation, and is rendered possible through the generosity of the United Fruit Company in kindly providing free passages in ships of the Elders and Fyffes Line. Professor Hardy returns to Trinidad in time for the next session, which opens on 3rd October.

AGRICULTURAL EXCURSIONS.

The Trip to the Islands.

24th March—2nd April.

On Thursday, 24th March, the College party collected on the jetty at about 4.30 p.m. and gave the impression of a very happy party of holiday makers complete with hat and camera, bargaining with a number of walking-stick vendors. Two launches took us out to the s.s. *Lady Drake*, a boat we discovered to be first-class in every respect. The boat left at 10 p.m. and provided a very beautiful trip through the Bocas by moonlight.

Anchor was dropped at Grenada at 7 a.m. next morning and after an early breakfast we were taken ashore by motor launch. The town of St. George is most picturesque, stretching back from a sheltered bay into the well-wooded hills. Mr. K. T. Rae, the Agricultural Superintendent, had ordered five taxis for transport but as we climbed ashore from the launch it looked as if every available car in the Island was waiting at our service. Finally we got into the right five cars and were taken to the Botanic Garden and then, further inland, to the Agricultural Department's experimental area. Most of this was under a large scale tomato trial which, unfortunately, has had to be abandoned on account of recent economy measures. A small dam and an irrigation system erected at the very moderate cost of £70 were of great interest in showing how difficulties of water supply can be met by the ingenuity of agricultural officers in isolated districts. Mr. Rae very kindly gave us refreshments of no mean order before we had to return to the boat at 11 a.m.

During the whole of the afternoon we passed a succession of volcanic Islands, many of them inhabited, while others were just rocks rising above the surface. St. Vincent presented a gorgeous spectacle in the late afternoon sunlight with its brightly coloured town at the base of high and densely green hills. We walked up to the Co-operative Cotton Ginnery accompanied by a crowd of small boys, curious to see so many people in khaki shorts, and anxious to point out Kingstown's features of interest, such as the Public Library and the local Bethesda. Unfortunately the Ginnery was not working but we were able to examine the machines and samples of lint. Soap is manufactured from the surplus cotton seed oil and the Co-operative Society also possesses excellent facilities for the storage of members' seed. There was just time to see the experimental cotton plots and further tomato fields before darkness descended and we made our return to the *Lady Drake*. One cannot easily forget the journey from the shore back to the boat; the harbour craft silhouetted against the last rays of the sunset sky, and the *Lady Drake* lying in the distance with its brightly lighted decks and gangway.

There was no mistaking our arrival at Barbados the following morning, when, through the porthole came the familiar shouts of "Throw me a dive, Boss," "*Lily White*, Sir," "Yes, Sir, *Lily White*, that's your boat." After breakfast the stalwarts of the *Lily White* and a couple of other rowboats took us ashore. The morning was quite one of the most interesting of the whole trip. We were first taken to the Headquarters of the Department of Agriculture, where Mr. R. W. E. Tucker very ably described and demonstrated the work which is being carried on in connection with the biological control of the cane borer (*Diatraea*) by *Trichogramma*. Later in the morning we visited the cane breeding plots and were given much interesting information on the technique and aims of cane breeding. The remainder of Saturday and Sunday were free and most of us enjoyed an excellent swim at the Aquatic Club.

The sun was just rising above the mountains of St. Lucia as we entered the harbour of Port Castries on Monday morning. Our luggage was taken up to the Hotel St. Antoine while we were taken straight off to the Government Experimental Station some miles inland. It was indeed of very great interest to see Mr. E. A. Walters' work on the vegetative propagation of pineapple, avocado and mango described in the February issue of *Tropical Agriculture*. The whole Station, including not only plants of horticultural and agricultural interest but also a small training centre for students, gave one the impression of extremely efficient management. The scenery is certainly some of the finest in the West Indies and the hotel where we returned for lunch commands a magnificent view of the harbour, Port Castries, and, in the distance, the Island of Martinique. That same afternoon we were driven right over the central range of mountains to the other side of the Island. The tortuous mountain roads pass through dense forest with clearings here and there. Above the 2,000 feet level

numerous tree ferns added to the beauty of the vegetation. At the top the view is exceptionally fine showing the steep volcanic mountains, heavily afforested, and the fertile alluvial plains passing down to the coast.

The following morning after an early breakfast we set out in a motor launch for the Souffrière district, aptly described by an inhabitant as "the garden of the Island". The journey of two hours was one of ever changing views of great beauty. The small communities of square wooden huts clustered together amidst the palm trees at the end of each valley, were strangely reminiscent of the illustrations of "Robinson Crusoe". As we rounded the final promontory the two Pitons rising 2,500 feet sheer from the sea, stood in majestic dignity. On shore the day was one of very great interest; our first visit was to one of the lime factories and the adjoining plantation which bore ample witness to the fertility of the soil and its suitability for lime cultivation. We then went on to the estate managed by Mr. Frew, a Scot, who gained our greatest admiration by the efficiency of his methods and practice. A small factory run entirely by water power is equipped with machinery for sawing and planing timber for the manufacture of wooden fruit boxes which are in increasing demand. A further section is devoted to extraction of limes and also carries a small machine for the decortication of coffee cherries. After an excellent lunch at Mr. Frew's we visited the plantations of the estate and were shown many points of practical value. Fishing was tried on the way home but with only very spasmodic success. Before embarking on the s.s. *Lady Nelson* the next day, further lime estates were visited and we were shown over the Government cold store which is playing an important part in the development of the soft fruit trade with Canada. Before leaving St. Lucia, mention must be made of the hospitality shown us by the members of the Vigie Club on the two evenings we were there.

The following day at Barbados was free, and again the Aquatic Club was very popular, in fact, the anchor of the *Lady Nelson* was raised before the last boat-load arrived on board. The following morning brought us once more to St. Vincent, where we were (once again) joined by the "specialists". During our two or three hours ashore we visited a large tomato plantation and the arrowroot factory. There seems to be considerable possibilities for the development of the tomato industry in some of the West Indian Islands, provided certain virulent diseases can be kept in check; the crop in St. Vincent appeared to be excellent in every respect save for the severe attack of Blossom End Rot having the popular local name of "Black Bottom".

At Grenada the same afternoon we were shown over the Government Packing Station where a number of different fruits were being canned and local drinks manufactured. Islands such as Grenada are in a very favourable position with the rapid ocean transport provided by well equipped boats to Canada and the United States, and the possibilities of fruit trade are now being widely explored. On Saturday morning, 2nd May, the familiar sight of the Northern Range and Central Plain of Trinidad greeted us once more. We returned to the College much refreshed both in mind and body after a most enjoyable trip, and grateful for the hospitality showered on us in the traditional West Indian manner.

"P. G."

EXAMINATION RESULTS.

DIPLOMA STUDENTS, 1931-1932.

(i) *4th Year* (*Sugar Technology*).—The special 4th year examination in Sugar Technology was passed by:

J. de Labastide.

(ii) *3rd Year* (*Standard*).—The following students passed the 3rd year examination and will be awarded the College Diploma:

J. M. Cave.
L. de Verteuil.
L. C. W. Greaves.
H. L. Manning.
S. A. Schouten.
J. Singh.

(iii) *2nd Year*.—The following students passed the 2nd year examination and are eligible to proceed to the 3rd year course:

M. Barcant.
J. M. McEwen.
H. C. Miller.
T. E. K. Potter.

(iv) *1st Year*.—The following students passed the 1st year examination and are eligible to proceed to the 2nd year course:

St. George Cooper.
B. Darwent.
V. O. Ferrer.
A. Garces.
A. D. Herbert.
C. M. Imamshah.
A. C. Suarez.

SPORTS.

[*The Editor is indebted to the Captain of the College Clubs for the information which he supplied for the following retrospects.*]

Hockey Club, 1931-32.

The season, on the whole, was a successful one, fourteen matches being played, of which nine were won and five lost. An excellent game was played against the Staff and several very good ones against the various units of the Navy on their visit to the Island. The College was successful in getting into the Final of the Knockout Competition, eliminating Queen's Park, the winners of the League, in the first round, and the Rovers in the second round. In the final the Wanderers proved altogether too fast for our backs and our forwards seemed unable to get together, but the game was by no means as one-sided as the score suggests.

Results :

Queen's Park	Won 2-0
Constabulary	Lost 1-2
Constabulary	Lost 0-1
Wanderers....	Won 4-2
Wanderers (final)	Lost 3-7
Rovers	Won 2-0
Usine Ste. Madeleine	Won 3-1
Pointe-à-Pierre	Won 5-4
Pointe-à-Pierre	Lost 2-6
Casuals	Won 6-0
Rugby Club	Won 5-1
H.M.S. *Hood*	Won 7-1
H.M.S. *Exeter*	Won 2-0
H.M.S. *Hood, Norfolk, Dorset*	Lost 2-3
Staff	Won 4-2

Played 14, won 9, lost 5; goals for—44, goals against—28.

The Team : H. L. Manning, D. W. Duthie, A. V. Richards, B. R. Jones, B. G. Charles (*Captain*), T. E. Potter, G. C. Stevenson, G. R. J. Murray, J. R. E. Hindson, A. K. Briant, J. J. Anderson.

* * *

Tennis Club, 1931-32.

The season, on the whole, was a successful one, though rain prevented play on at least three occasions. Of the six matches played, three were won and three lost, while, in the two Staff *versus* Students matches, the former won on both occasions by a small margin.

A good entry of forty-eight was obtained for the College handicap singles tournament, which was won by J. A. McDonald, who beat L. de Verteuil in the final by 6-3, 6-4, 3-6, 6-3, after an excellent game.

The team : J. A. McDonald, G. G. Gianetti, L. de Verteuil, M. Barcant, Y. Israsena, P. C. Chambers, J. R. E. Hindson, B. G. Charles (*Captain*), while A. Garces, A. C. Suarez and H. Gillman also played in some matches.

OLD STUDENTS' CORNER.

G. Cowan (1927-28) is stationed at Tamale, Northern Territories, Gold Coast. Shortly after he came back from leave he did two months trekking on locust control which he found very interesting and strenuous. He also acted for some time as Provincial Superintendent in the place of J. E. Symond (1926-27), who had gone on leave. Both he and C. W. Lynn (1928-29) have been mastering the vernacular. During their spare time they shoot big game and play polo, Lynn being Secretary to the local club.

* * *

R. W. R. Lever (1929-30), who is stationed in the Solomon Islands as Government Entomologist, is finding both the plant and insect life there full of interest. He was delighted to learn that some of the insects he discovered and submitted to the Imperial Institute of Entomology are new to science. He is also rapidly mastering the Pigeon English of the Melanesians.

* * *

C. Maher (1928-29), who is stationed at Kitale, Kenya Colony, was married last year. He is now in charge of the Nasui Gishy Province, including Eldoret, and the Plateau wheat growing districts. His district has been severely affected by locusts and his chief concern has been to protect the maize breeding plots from these pests.

* * *

T. G. Strangeways (1930-31) is now quite settled down in the Gold Coast, where he is having a busy time forming Co-operative Societies among the farmers in his District, Utrokpe. His house, he says, is a native mud-hut so greatly improved that its only drawback is the heat at night, for it takes some time to cool off.

* * *

J. D. E. F. Vezey-Fitzgerald (1931-32) has been appointed by the Sugar-Cane Investigation Committee, Trinidad and Tobago, Assistant to Dr. J. G. Myers, Entomologist in charge of the Biological Control of Insect Pests in the West Indies.

* * *

G. W. Lock (1929-30) wrote some time ago from Tanganyika that he had been transferred from Headquarters at Morogoro to Tanga, where he is acting as District Agricultural Officer as well as carrying on the Sisal Survey.

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CHEMICAL NOTES.

Compiled by the College Department of Chemistry and Soil Science.

The Influence of the Ratio, K_2O to N, on the Development of the Coffee Tree during its First Vegetative Period. T. de Camargo.

These experiments on coffee nutrition were carried out in pots with soils of low nitrogen, phosphate and potash contents, as well as in synthetic culture media; they were controlled further by field experiments. Under these conditions, the author observes that *phosphorus is the element which has the most marked influence on the development of the roots, stems and leaves of Coffee.* Added in excess, phosphate does not produce any harmful action on the growth of the plants. The same does not hold, however, for potash and nitrogen; these cannot be added arbitrarily. To control their action, the author conducted experiments in pots holding 30 kgs. of red soil maintained at constant moisture content. When the quantity of nitrogen is constant, increase in potash above a certain limit produces a marked decrease in yield. Similarly, when the quantity of potash remains constant, decrease of nitrogen is followed by a decrease in yield. The interdependence of the two elements is thus evident. Repeating these experiments with nutrient solutions renewed every week and placed in Pyrex glass vessels of such a shape that the solutions are kept in constant movement, the author has proved that, up to 18 months, the optimum potash-nitrogen ratio for the coffee tree (*Coffea arabica* L.) is between 0.5 and unity. As a general rule, the maximum amount of mineral elements in the different organs coincides with the maximum weight of the plant, except in the case of potash which decreases in the stem as the quantity of nitrogen increases in the culture medium. Determination of some of the chief plant organic components has shown that the quantities of protein, sugar, starch and cellulose contained in the leaves vary directly with the weight of the plants, that is to say, they show a maximum value when the ratio potash-nitrogen is unity, while the quantities of glucose and of a methylpentoses vary inversely with this ratio. —(Abstract from the *Proc. Int. Soc. Soil Sci.*, 1932, Vol. VII, No. 1, p. 23.)

* * *

Cotton for Roads.

According to the *Contract Journal*, Dr. Pickard, President-elect, has disclosed a new use for cotton fabrics. "At the present time," said Dr. Pickard, "whenever it is necessary to mend the roads, not only the surface but the sub-surface and even the very foundations have to be dug up. By inserting a layer of cotton fabric between the surface of the road and the sub-surface, it is possible, when the roadway becomes worn, to flake off the upper surface, without disturbing the foundations. For this purpose a cheap cotton fabric can be used, similar to that used to protect meat".—(*Chem. & Ind.*, Vol. L., 1932, No. 27, p. 577.)

Simple Graphs for Calculating Lime Requirements.

In a short paper published in the June, 1932, issue of the *Proceedings of the Sugar-cane Investigation Committee*, Trinidad, Professor F. Hardy presents a diagram comprising four graphs from which the approximate lime requirements of soils of the sugar-cane lands of Trinidad may quickly be assessed by mere inspection. The four graphs refer to (*a*) *sands*, whose Indices of Texture arbitrarily lie between the values 0 and 20, (*b*) *loams*, with indices between 20 and 40, (*c*) *silts*, with indices between 40 and 55, and (*d*) *clays*, with indices between 55 and 65. The vertical ordinate of the graphs gives degrees of acidity (pH values between 4.0 and 7.4), and the horizontal ordinate gives theoretical lime requirement values in tons of ground limestone per acre-foot of soil. The graphs were constructed from experimentally-determined lime-requirement values for a great number of soil samples belonging to different texture and reaction categories, collected during the detailed cane-lands soil survey of Trinidad, performed during the years 1926 to 1930. The lime requirements were determined in the laboratory by an electrode method devised in 1929 by F. Hardy and A. H. Lewis at the Imperial College of Tropical Agriculture. Practical lime requirement values, for various stated reasons discussed in the paper, are about three times the magnitude of the theoretical values as determined by this method.

The lime-requirement graphs are to be used in conjunction with soil maps. For this purpose, texture and reaction values for each of the several thousand spot soil samples procured during the survey have been plotted in colours on separate texture and reaction sugar-estate soil maps. Copies of these maps have been distributed among the estate proprietors or managers whose lands were surveyed. By reference to the detailed maps and to the simple graphs, the approximate lime requirement of almost any field or area within the cane-growing region of Trinidad may readily be determined by inspection. This obviates the necessity of procuring special soil samples for laboratory examination from fields requiring lime, and a great saving of expense, time and labour is thus effected.

* * *

Relative Effectiveness in Soils of Limestone Particles of Different Sizes.

At Cornell University T. L. Lyon found that finely-ground limestone (less than 200 mesh) had a rapid action on acid soils, but the resulting crop increases were mainly confined to the years immediately following the application. Very coarse particles (5-10 mesh) showed no cumulative effect in the ten years under examination. Most satisfactory results are indicated with samples of soft limestone ground completely to pass ten mesh. A suitable proportion of finer particles is thereby obtained. Hard stone should be more finely ground. — (*Chem. and Ind.*, Vol. LI, No. 22, 1932. Abstracts B, p. 440.)

TREND OF THE MARKETS.

[*The notes below are based principally upon running charts of the prices of the basic grades and upon general statistical information gleaned from contemporary publications and cablegrams and are intended to be a record of movements. An attempt is made, where possible, to indicate the market outlook at the time of going to press, but no responsibility for the accuracy and subsequent truth of such observations is assumed. Unless otherwise stated the prices quoted are spot, London.*]

SUGAR.—Prices on the Home Market have ranged as follows (c.i.f. per cwt.) :—

	Foreign.	*Preferential.*
	s. d.	*s. d.*
30th June ..	5 9	10 6
7th July ..	6 0	10 9
14th July ..	6 1⅓	10 10½
21st July ..	6 2¼	10 10½
28th July ..	6 3	10 10½
4th Aug. ..	6 3	—
11th Aug. ..	6 6¾	—
7th Aug. (1931)	6 5¼	10 2¼

The market has been firm with a general tendency for advances in price. The adjournment of the Conference of the International Sugar Council, which opened at Ostend on 7th July, without any definite agreement, caused a temporary set back. There was a quick recovery. The appearance of the European beet crop is good. Favourable weather is reported from Germany, Czecho-Slovakia and France.

* * *

RUBBER.—Quotations for Plantation Sheet have ranged as follows :—

	d.
29th June	1 3/16
6th July	1 3/16
13th July	1 2/32
20th July	1 2/32
27th July	2 1/32
3rd Aug.	2 1/16
10th Aug.	2 1/16
12th Aug. (1931)	2 1/16

The market has been more active, and consistent fractional advances in prices have been gained. The Lausanne Conference, the reduction in the Bank Rate, and the War Loan Conversion Scheme point to greater confidence, and a prolonged period of cheap money. The publication of corrected figures of stocks held in Singapore strengthened the position. The total stock held by dealers in the Straits Settlements at the end of June amounted to 23,331 tons compared with 42,041 tons at the end of May, the difference being accounted for not by heavy shipments in June but the discovery of cumulative errors in the returns furnished by Dealers over a considerable period.

* * *

COPRA is a quiet, but steady market, quotations for West Indian f.m.s. being £14 7s. 6*d.* for forward, and £14 5s. near c.i.f. London.—(*West India Committee Circular*, 21st July.)

COCOA.—Last advices by mail report new crop good fermented Accra at 26s. 9*d.*, c.i.f. Continent, London spot prices are quoted at Trinidad 41s. to 52s., Grenada 38s., Costa Rica 31-32s. 6*d.*, Maracaibo 112s. 6d., and Ceylon 50-67s., with business practically at a standstill. Subsequent cable advices report a steadier market and with a better feeling prevailing in stock markets generally and prominent rises in wheat, sugar and cotton it is hoped that cocoa prices will now show an advancing tendency.—(*By courtesy of the Cocoa Planters' Association of Trinidad Limited.*)

* * *

COTTON.—The following are the official spot prices in pence per lb., of the Liverpool Cotton Association :—

	American Mid.	*Egyptian F.G.F. Sakel.*
24th June ..	4.41	6.30
1st July ..	4.65	6.40
8th July ..	4.87	6.90
15th July ..	4.66	6.65
22nd July ..	4.56	6.90
29th July ..	4.67	—
5th Aug. ..	4.69	—
7th Aug. (1931) ..	4.29	6.55

The moderate advance in prices culminated on 7th June owing to a tendency to liquidate. There is unlikely to be any marked improvement until the general political situation yields more definite results. An increasing number of complaints of wet weather and fear of boll-weevil activity is being received.

* * *

BANANAS.—The English soft fruit season continues to affect the demand. Prices are unchanged at £20 5s. per ton delivered London, or £20 nearest railway station for Jamaicas; and £18 per ton delivered nearest station for Brazilians. —(*West India Committee Circular*, 21st July.)

* * *

LIME PRODUCTS.—There is no market change in these products to report, business being negligible. Values remain nominally as quoted in the last summary: *Lime Oil.*—Handpressed on the spot 55s.; Distilled 32s. to 32s. 6*d.* *Lime Juice.*—Raw, 2s. to 2s. 9*d.* for good Dominica to fine Jamaica. — (*West India Committee Circular*, 21st July.)

* * *

SPICES.—A small business is being done in *Pimento* around 21s. 6*d.* c.i.f. for July-August shipment, with further offers at the same price, while sellers quote 22s. A considerable business in *Ginger* has been done in parcels on the spot, at prices ranging from 52s. 6*d.* up to 95s. per cwt., according to quality. *Nutmegs* have been neglected. The value on the spot remaining unchanged at 4½*d.* to 10*d.* for 110's to 62's.—(*West India Committee Circular* 21st *July.*)